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AN INTRODUCTION
TO THE
GRAPHIC LANGUAGE

THE VOCABULARY, GRAMMATICAL CONSTRUCTION, IDIOMATIC USE, AND HISTORICAL DEVELOPMENT WITH SPECIAL REFERENCE TO THE READING OF DRAWINGS

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PREFACE

This treatise is designed to present in logical form an outline of the construction, idiomatic use, and vocabulary of the one universal language in such manner as to emphasize its relation to other languages and enable one to obtain a reading knowledge in the most direct manner.

Although every one is at times called on to read drawings descriptive of architectural or engineering construction, few have the ability to read with full understanding the graphic description of the plan of a house. This is due to the fact that instruction in the language has been largely confined to technical education and associated with mechanical technique and penmanship. Because of this, the present treatise has been planned as a reading course involving the minimum of drawing, and that, mostly freehand in character.

The term Mechanical Drawing has been responsible for much that has limited the field of this language to geometry and penmanship, leaving its great function, the art of expression, almost untouched. Indeed, the subject can be properly taught only from the standpoint of language.

A feature of this treatise which has been entirely ignored in the past is the presentation of the historical background of the language, and its relation to the world's progress in arts and sciences. It is a matter of great surprise to many that Leonardo da Vinci was one of the greatest engineers that the world has known and that some of the great inventions of this day were anticipated and graphically recorded in many volumes of his drawings; that he developed the theory of perspective and made use of it for transcribing his technical ideas. It is not generally known that the theory of projection or the grammatical construction of the Graphic Language was not used until the beginning of the nineteenth century and that the idiomatic use of the language is a development of the past three decades.

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The subject of penmanship, including the use of instruments, lettering, and applied geometry, — much that is properly speaking Mechanical Drawing, — is treated in Part II, which may be used when required and in the degree necessary. Indeed, a proper use of the lead pencil and compasses together with cross-section paper is the most that is required for the practice work of the proposed course.

The treatise is designed not only for the non-technical student and reader, but as an introductory course for technical schools, since it presents a comprehensive view of the language, and in the author's opinion comprises the best preparation for the technical college.

As a course of instruction for colleges, it has been used, before publication, in a School of Liberal Arts, a College for Women and Dental School, as well as an introduction to a Technical Drawing Course in an Engineering School.

The entire course need not require more than one hundred hours and has been given in much less time. By the use of cross-section and tracing paper much of the usual equipment for a course in Mechanical Drawing will not be required.

The author will be glad to assist teachers in outlining courses of instruction.

TUFTS COLLEGE, MASSACHUSETTS
February, 1922.

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AN INTRODUCTION TO THE GRAPHIC LANGUAGE

PART I

CHAPTER I

READING LESSONS AND PICTORIAL GRAPHICS

1. Language being the principal medium for the interchange of thought is the one essential requirement for education and without it civilization would be impossible. In order that education be broad and include more than is comprised in the written thought of one country, a knowledge of more than one language is necessary since there is no universal language which is both spoken and written. There is, however, a written language which is universal although somewhat restricted in certain fields of expression. This language is Graphics, or what is commonly called drawing.

2. Graphic Language. — The term drawing bears the same relation to Graphics that penmanship does to English. In painting a picture the artist aims to express some definite idea, such as the grandeur of a storm, or the peace and beauty of a rural scene. He is not so much concerned with the outline of a wave or of a tree or the reproduction of the exact color, as with imparting to the beholder the impression which has been created in his mind. The ability to portray this idea is a measure of the artist's ability to express himself in graphic language. One may be skilled in the use of pencil and brush, and versed in the technique of art, yet incapable of expressing ideas by this medium. This is true of all phases of draftsmanship and design since the graphic language possesses its own idioms and its subtle forms of expression which are independent of penmanship.

During the last half century the development of graphic language has been very great, but the appreciation of its universality as a medium for expression has been largely confined to the professions of architecture and engineering. Even these have been slow to avail themselves of its great possibilities, to appreciate its idiomatic character and its richness in forms of expression. In the field of education the principal stress has been laid on the penmanship of free-hand and mechanical drawing to the neglect of practice in reading the graphic language and in giving expression to one's ideas through this medium.

3. Plan of Course. — In this treatise the subject is treated from the language point of view, and in such a manner as to make it of service to those who desire only a reading knowledge of the language, as well as to those who may become more skilled in interpreting their ideas through this medium. To this end the instruction is so given that it will be possible for one to pursue an elementary course in reading which will include the minimum of penmanship, or drawing, but which will serve as an introduction to a more exacting course in the interpretation of such complex ideas as machine construction.

The first study consists of the reading of simple house plans such as are expressed by two dimensions, but including a third dimension in the consideration of such features as stairs.

The second study treats of geological survey maps which include contours. These give a reading practice similar to the first study, and in the drawing of profiles the contours will serve to introduce the third dimension in much the same manner as do the stairs of a house plan.

The third study deals with the elements of perspective. This is to serve as an introduction to other than the picture type of

Graphics. One is most accustomed to interpreting thought graphically through the medium of perspective because it is of the same character as the impression produced on the eye.

The fourth study includes some of the substitute methods for perspective representation which may be used more easily and which will serve the student as a simple means for expressing his ideas graphically to the instructor.

The fifth study treats of orthographic projection. It will comprise the vocabulary and the grammatical construction of the graphic language together with the exceptions, or idioms, which serve to make it concise and expressive.

The sixth study gives consideration to the idioms and their practical application to the simplification of the language both for reading and writing.

The seventh study may properly be termed an introduction to the understanding of the literature of the graphic language.

Since the history of this language has never been written some of the studies are accompanied by a brief history of the origin and development of Graphics as related to the subjects treated.

A supplementary course (Part II) in the use of the essential instruments will include the more practical geometrical problems and lettering, thus presenting the essentials of graphic penmanship. This may be used to such an extent as the time and thoroughness of the course make desirable.

4. The Vocabulary. — In order to obtain the information which a drawing is designed to impart, it is necessary to become familiar with the notation, or vocabulary, which is used to describe the character of the material used in the several trades and professions and which require different symbols for graphic expression, as is the case with other written languages, save that a sign is used in place of a word. It is not uncommon to speak of such a collection of signs, or symbols, as a Graphic Dictionary.

The vocabularies are distributed throughout the text as required for the reading of the drawings, and a few special vocabularies are printed on pages 154 to 160.

5. To Read a Drawing is to create a mental picture of the object which may have been, or is designed to be, constructed. The lines and conventional signs of the drawing are devised to convey an accurate and complete concept of the object in the same manner that words and sentences produce mental pictures, but with the added advantage that the geometrical relations are more accurately and quickly conveyed to the mind by a sign language which is truly universal. This is shown in the Architectural Vocabulary, Fig. 1, in which two equidistant lines on the plan of a house indicate the walls, another combination of parallel lines a window, and a break in the wall space accompanied by a slant line represents a door. Similarly all of the parts and fixtures of a house may be designated and read with great ease, provided one understands the notation, or vocabulary, of the language. In the case of house plans and contour maps, it is necessary to use one's imagination in order to add a third dimension, height, but this may be suggested by certain lines such as are used to indicate the stairs of a house, or contour lines which represent elevations on the map of a hilly country.

6. Architectural Reading. — Because of the general familiarity with the arrangement and equipment of houses a study of the plans, or drawings, descriptive of architectural construction is the best introduction to the reading of Graphics.

7. The Architectural Vocabulary. — Fig. 1 is a representation of some of the symbols which are used to express the character of the parts of a house and its fittings. It is important that the reader of Graphics should become familiar with the more important of them, and especially those included under the heading of " Structural Vocabulary."

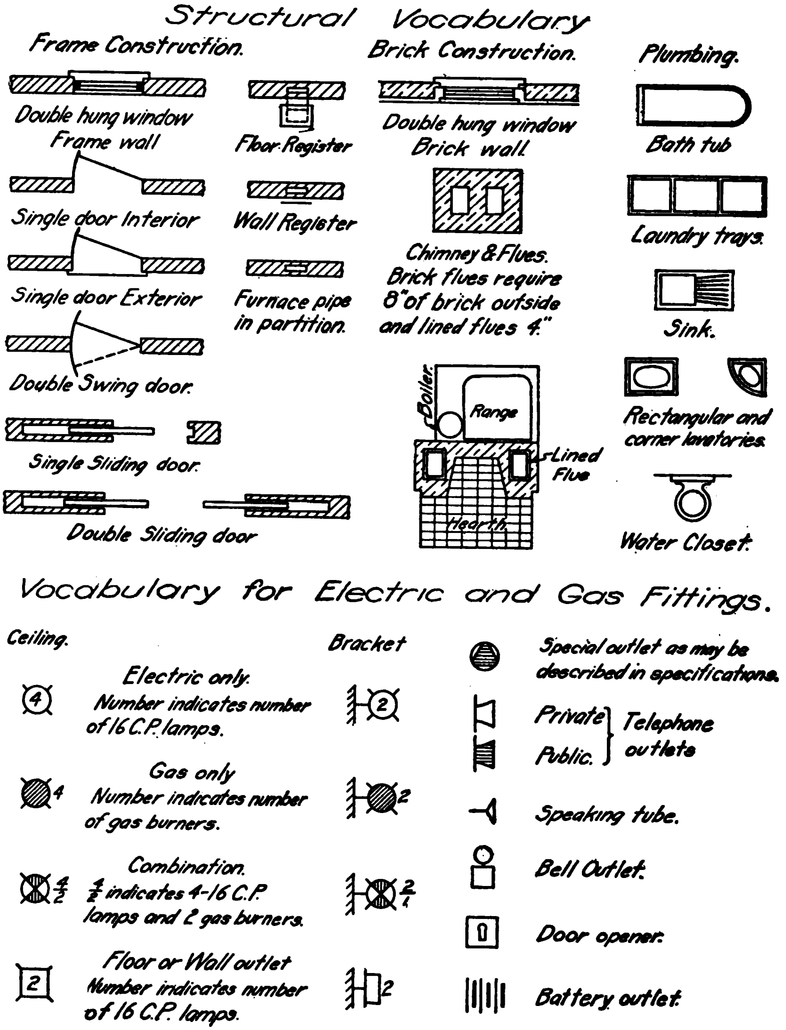

FIG. 1. — ARCHITECTURAL VOCABULARY

8. The Scale. — In order that the dimensions of an object, graphically expressed, may be read with accuracy, it is customary to make the representation to a certain scale, or proportion, which in the case of house plans is commonly ¼″ = 1 ft. This signifies that every quarter inch of the drawing is to be regarded as one foot in actual construction, and every eighth of an inch will represent six inches. In speaking of the dimensions of a drawing it is customary to name only the real, or full size dimension of the object, regardless of the diminished size to which it may be necessary to make the drawing. Failure to do this will produce great confusion.

The unit scale is varied to suit the convenience of the draftsman, or the size of the paper on which the drawing must be made. In architectural work scales of ⅛″ = 1 ft. and ¼″ = 1 ft. are commonly used for the plans of buildings, while other scales such as 1½″ = 1 ft. and 3″ = 1 ft. are used for parts which require a more complete representation. Such drawings are known as details.

Special measuring instruments known as Architects' or Engineers' Scales are made with graduated divisions to indicate the several scales used. Such instruments, or scales, are not absolutely necessary, as any scale divided into sixteenths of an inch may be used for a variety of scales by a little mental effort in conceiving one or more of its divisions as representing the desired unit for the reduced scale.

9. To Read the Plans of a House. — The first, second, and third floor plans of a house are described by Figs. 2, 3, and 4. Fig. 5 gives one view of the exterior and is known as an elevation. The latter is not necessary to an understanding of the plans, although necessary for the construction. Fig. 8, page 14, is a sectional view made to represent the appearance obtained by removing the front of the building.

It is required to obtain familiarity with the general arrangement of the rooms, their relation to each other, and the details of important structural features, such as doors, windows, chimneys, plumbing, heating and lighting fixtures. A study of the plan should enable one to obtain a better understanding of the relation of the rooms on the several floors than would be possible from a single visit to the house, and this is due to the absence of confusion caused by walking from room to room, and floor to floor.

The construction of a house should never be begun until it has been mentally occupied for such length of time as will enable one to become perfectly acquainted with its arrangement. This knowledge may be acquired in the following manner. Having become familiar with the architectural notation, or vocabulary, Fig. 1, make a study of the several plans after the manner described in the following study of Figs. 2, 3, and 4.

Referring to the first floor plan, Fig. 2, page 8, imagine that you have entered by the front door from the covered porch, swinging the door to the left, and are now in the hall facing the front stairs. Turn to the right and enter the parlor by the sliding doorway; go to the front window and station yourself at the point *A*. As one looks from this point into the hall through the sliding doorway the view of the hall is limited by the lines drawn from the observer and touching the door frames. This would comprise a view of the stairs up to and including the sixth stair. One could look into the dining room also, and if the doors were wide open it would be possible to look into the passage between the dining room and kitchen; a part of the south wall could be seen together with the register in the floor. In the hall, a part of the floor register could be seen, also the lighting fixture suspended from the hall ceiling, although the upper part of it may be concealed by the top of the door casing. Looking toward the library, nearly the whole of the south wall would be visible, save that upper portion which may be concealed by the upper part of the door frame. One window would be seen and the lighting fixture suspended from the ceiling. This fixture is provided with four gas and four electric outlets. (See the vocabulary, page 5.)

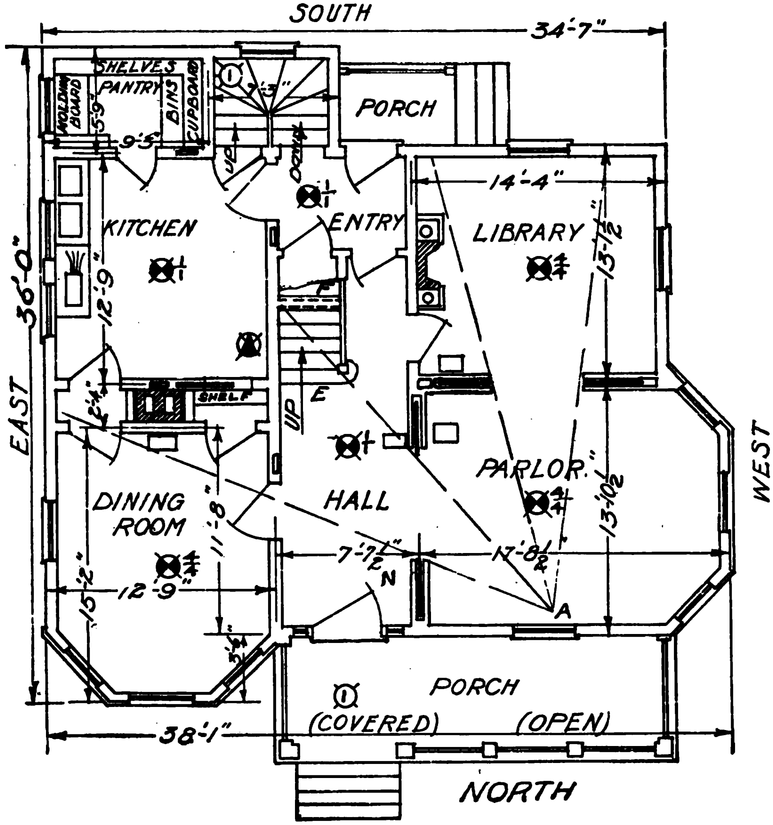

FIG. 2. — FIRST FLOOR PLAN NO. 1.

Next change the point of observation by entering the library and viewing the several rooms from a new position, looking for features which may be indicated on the ceiling, or floor, as well as the relation of the rooms. Thus move about the first floor to obtain a complete understanding of the convenience and attractiveness of the arrangement.

10. The Stairs. — Continue the observation by going up the front stairs from point *E* to the second story. These stairs are shown against the east wall of the hall. In looking at the drawing, their height, or "rise," cannot be seen, but if the height from the first to the second floor be known, as is shown in the sectional elevation, Fig. 8, page 14, and the number of steps be counted from the plan, the height or rise of each stair can be determined.

The arrow indicates that the stairs rise from the first floor at *E* and continue for seven steps, at which point an incomplete stair is shown at *F*. From this point the plan shows only the first story floor and a closet under the stairs. The continuation of the front stairs is shown on the second floor plan, Fig. 3, page 10, on which the corresponding stair is also marked *F*. This might have been determined by locating the front edge of stair *F* from some line common to both plans, such as the outside of the north side of the house. Continuing up the stairs from this point, as shown on the second floor plan, one steps up five more stairs on to a landing. From here it is necessary to go in the opposite direction up the three remaining steps to land on the second floor.

There are fifteen steps from the first to the second floor, the 15th being the step on to the floor. Since the distance from the first floor to the second floor, as shown by the sectional view of Fig. 8, page 14, is 8′-6″ plus 12″, equals 9′-6″, or 114″, the height of each stair will be 114 divided by 15, which equals 7.6″. The names of the several parts of the stairs are shown in Fig. 9, page 14.

11. The Second Floor. — Fig. 3. If one were to stand at the top of the stairs on the second floor, consider what might be seen from this point. Count the number of rooms into which one may look if the doors are open, and the part of each room that is visible. Consider the dimensions of the hall and the source of lighting from the outside, whether it is by direct light from the windows, or indirectly from the rooms and other halls.

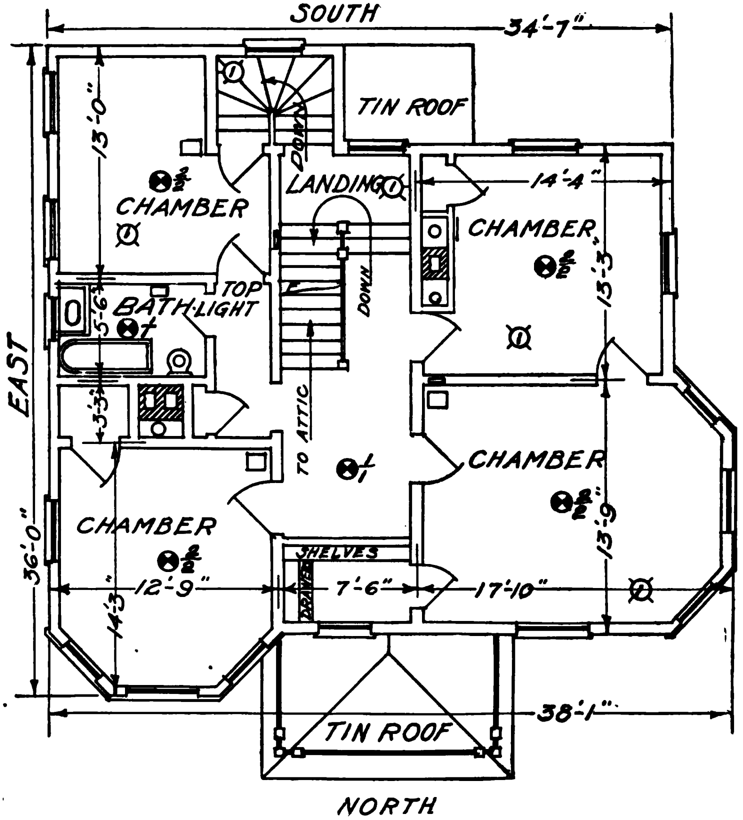

FIG. 3. — SECOND FLOOR PLAN NO. 1.

Thus, if we look down on to the stair landing, a window will be seen on its opposite side which lights the stairs and upper hall in an admirable manner. There is also an electric light bracket on the west wall, and to the left of the window is the door opening on to the back stairs down which one might look if the door were open.

In this manner assume other positions on the second floor in order to gain familiarity with it, and to judge of its convenience and fixtures.

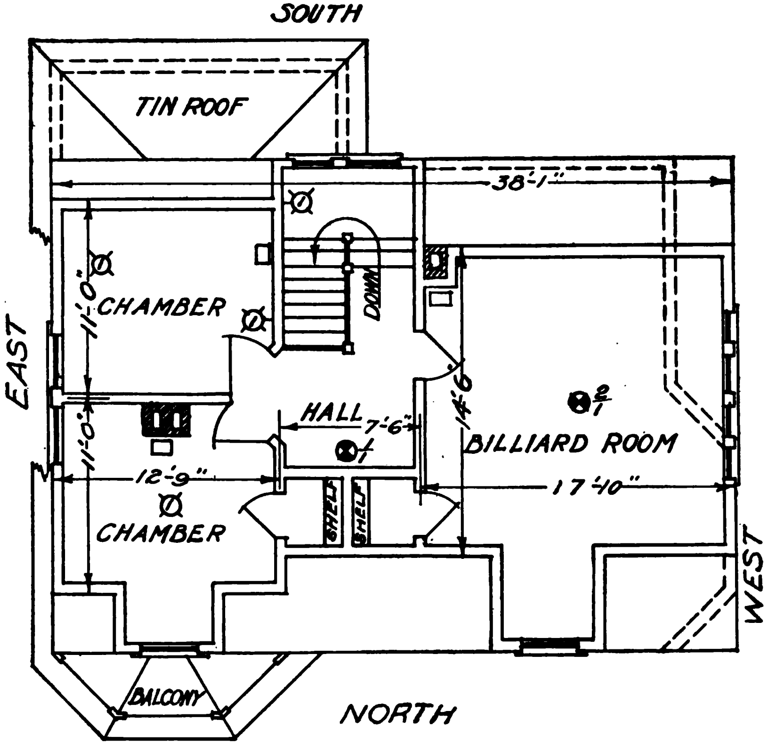

FIG. 4. — THIRD FLOOR PLAN NO. 1.

12. The Third Floor. — This plan, Fig. 4, shows a floor area much less than that of the previous plans and this is due to the pitch of the roof, the angle of which is shown in Fig. 8, page 14, and also in the elevation, Fig. 5, page 12. The outer wall of the room is shown in Fig. 8 to be brought in toward the center of the house for the purpose of obtaining the necessary head room, which is shown to be 7′0″ at the outer wall.

In viewing the several rooms note the method of heating them. Thus in the southeast corner of the billiard room a floor register

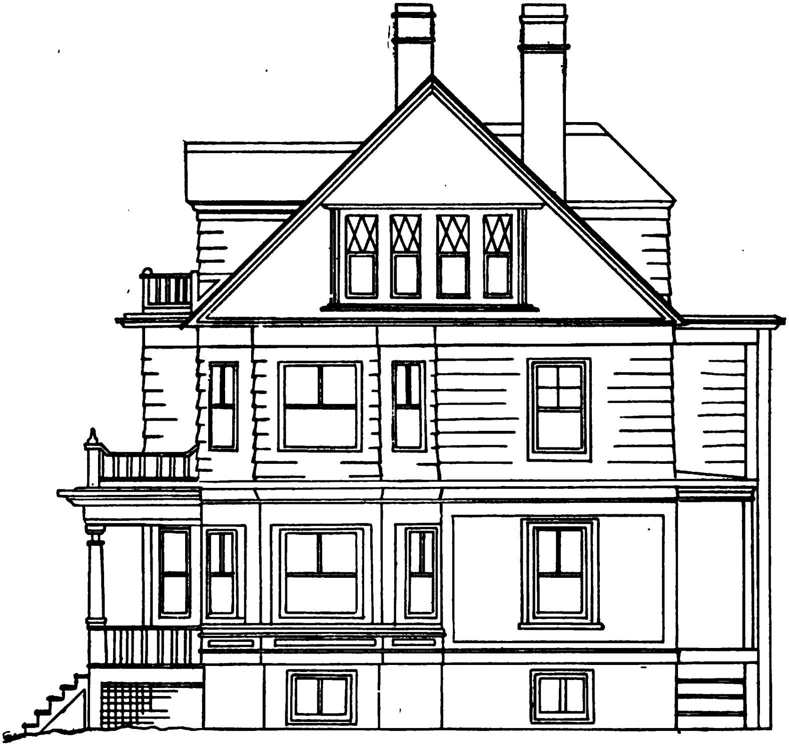

FIG. 5.—WEST ELEVATION PLAN. NO. 1.

is indicated, (see vocabulary in Fig. 1, page 5) and supplied from a circular furnace pipe built into the space by the side of a flue. This pipe can be seen on the second and first floor plans, and if a basement plan had been presented, its connection with the furnace would have been shown.

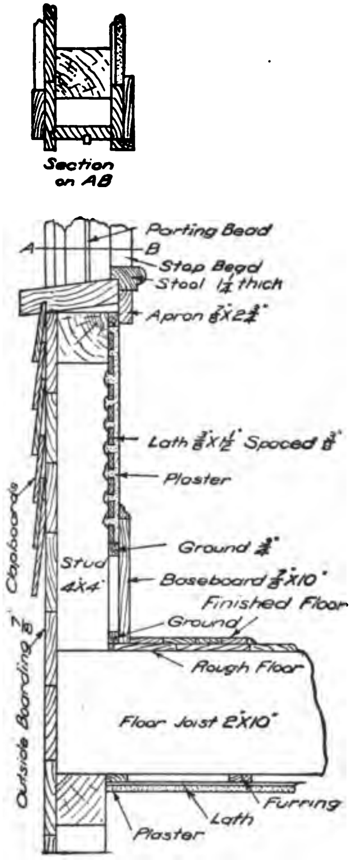

FIG. 6. — SECTIONAL VIEWS OF WALL. PLAN NO. 1.

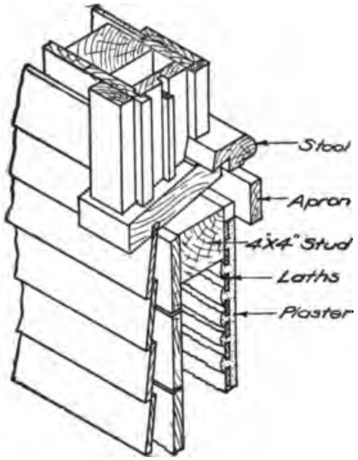

FIG. 7. — ISOMETRIC OF WALL. PLAN NO. 1.

13. Details. — Figs. 6 and 7 illustrate some details of construction relating to the outside walls which have an important bearing on the dimensioning of the plans. The walls of a frame building, or wooden house, consist of shingles or clapboards on the outside, fastened to rough boarding which in turn is nailed to the upright timbers, or studs. On the inside of the house, the laths are nailed to the studs and the plaster laid on the laths. The thickness of the wall, as represented in the sectional view, is 6½″, or from the outside of the boarding to the inside face of the plaster, 5⅝″. This is usually figured as 6″ for simplicity. Similarly the inside partitions between rooms are figured as of the same thickness as the outside walls, although

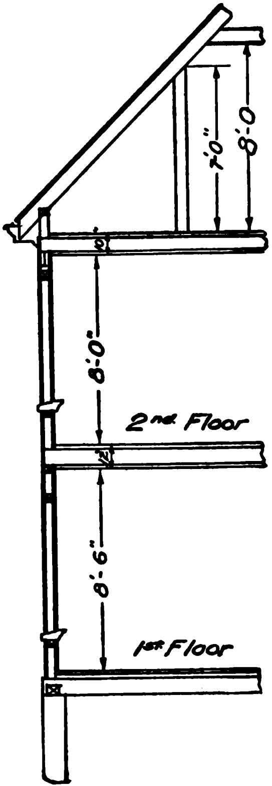

FIG. 8. — SECTIONAL VIEW.
PLAN NO. 1.

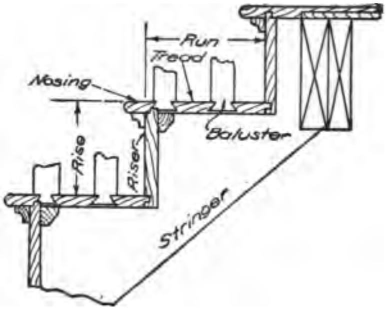

FIG. 9. — SECTIONAL VIEW OF STAIRS.
PLAN NO. 1.

differing slightly. They are usually constructed of 2×4 studs with ¾″ of lath and plaster on each side. They may be reduced to a little less than 4″, when necessary, by placing the studs edgewise, and may be increased to 9″ for partitions in which doors are made to slide.

The floor plans are commonly dimensioned from the outside of the walls to the center of partitions. Thus, the width of the dining room, exclusive of the base board, would be 12′-9″ less 6″+3″ or 12′-0″. The length would be 15′-2″ less 6″ + 2″ or 14′-6″, the partition in front of the chimney being made but 4″ thick. Again the width of the hall would be 7′-7½″ less 3″ + 4½″ or 7′-0″, since the sliding door partition is 9″ thick.

If the exact floor space were required it would be necessary to deduct twice the thickness of the base boards, or 1¾″.

14. Stair Details. — Fig. 9 represents a cross section of the stairs with the names of the several parts. The proportion of the "rise" to the "run" is of much importance, as it is governed by the natural pace of a person, which is much less when ascending than when walking on a level surface. The generally accepted proportion is to make the product of the "rise" and "run" equal 72. This product should not be less than 70 or greater than 75. The proportion illustrated by Fig. 9 is a good one and makes easy stairs. The limit for the "rise" in a dwelling house is from 7″ to 8″.

Questions on the Reading of House Plans — No. 1.

See Figs. 2 to 9

1. How many rooms are there in the house?
2. If one stood at point *N* in the hall with doors open, —
   (*a*) Into what rooms could one look?
   (*b*) How many doorways would be visible?
   (*c*) How many windows would be visible?
3. If one stood under the lighting fixture in the second floor hall and all doors were wide open, —
   (*a*) Into what rooms could one look?
   (*b*) How many doorways would be visible?
   (*c*) How many windows would be visible?
4. Enumerate all of the details of the house on floor, walls, and ceiling visible to one who stands under the lighting fixture in the library.
5. Enumerate all of the details of the house on floor, walls, and ceiling visible to one who stands under the lighting fixture in the S. W. chamber, 2nd floor.
6. Are all the chambers provided with closets?
7. If all the doors on the second floor were closed, what would be the source of daylight for lighting the 2nd floor hall?
8. How many electric light bulbs must be provided for the first story rooms and halls?
9. For how many gas burners has provision been made on the first and second floors?
10. What rooms are heated by wall registers?

11. * Give the dimensions between the walls of the parlor.
12. * Give the dimensions between the walls of the library.
13. * Give the dimensions between the walls of the N. W. chambers
14. * If it were required to carpet the S. W. chamber, 2nd story, how many yards would be required if the carpet is one yard wide?
15 Where should the bed be placed in S. E. chamber, 3d story?
16. Where should the bed be placed in the N. E. chamber, 3d story? Is the position of the lighting bracket satisfactory?
17. Would you suggest a change in the swinging of any of the chamber doors on the 2nd and 3d stories?
18. Are all of the rooms heated and are the furnace pipes concealed in all cases?
19. Has provision been made for a gas range in the kitchen? If so, where?
20. For what purpose are the spaces utilized to right and left of the library fire-place?
21. What should be the rise and run of the stairs in going from the 1st to the 2nd story?
22. How many steps up must one make in going from the 2nd to the 3d story?
23. What must be the rise and run of the stairs from the 2nd to the 3d story?

Questions on the Reading of House Plans — No. 2.

Figs. 10 to 15

1. How many rooms are there in the house?
2. How many chambers are there?
3. Is there a closet in each chamber?
4. If one stood at the point *M* in the 1st floor hall and all the doors were open, —
    (*a*) Into what rooms could one look?
    (*b*) How many doorways would be visible?
    (*c*) How many windows would be visible?

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* **A scale must not be used in problems 11 to 14**

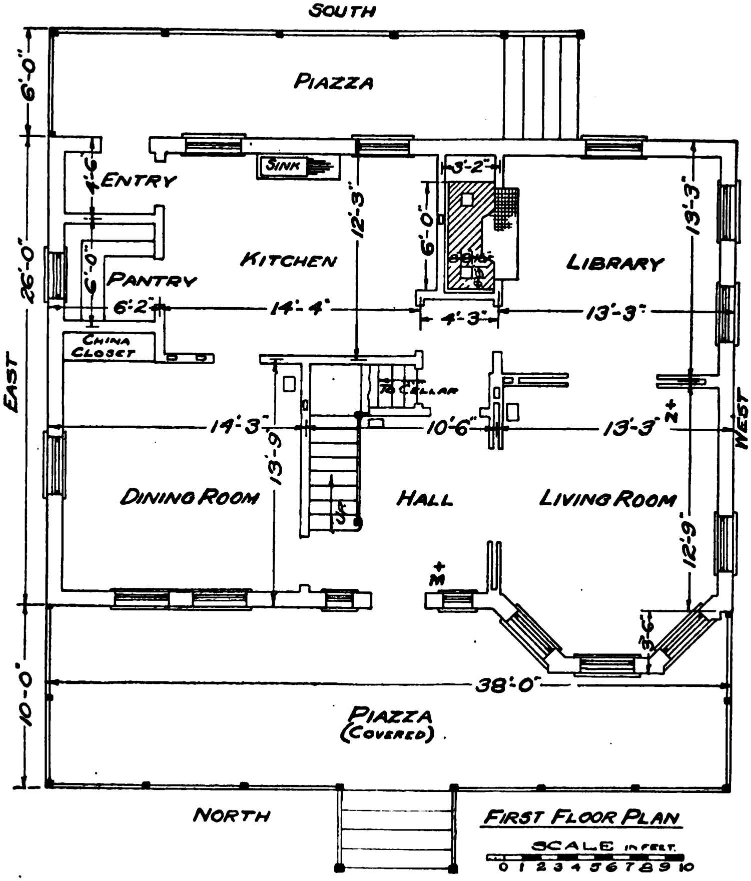


FIG. 10. — PLAN NO. 2.

5. If one stood at the center of the north window in the living room and all the doors were open, —
    - (*a*) Into what rooms could one look?
    - (*b*) How many doorways would be visible?
    - (*c*) How many windows would be visible?
    - (*d*) How many floor registers would be visible?
    - (*e*) How many stair treads would be visible?

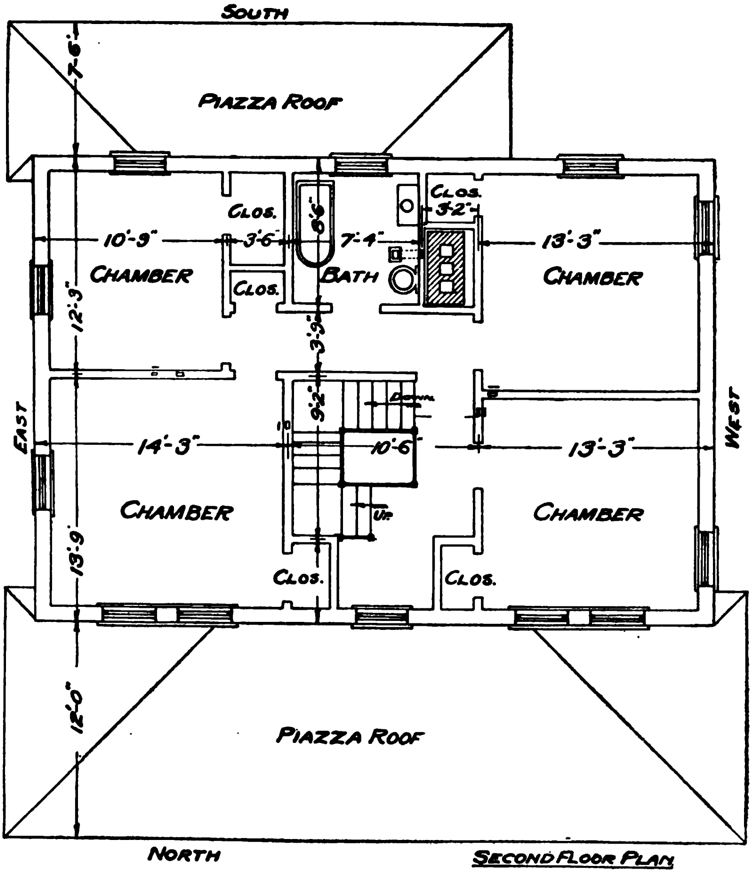


FIG. 11. — PLAN NO. 2.

6. What rooms are heated by wall registers?
7. Are any rooms not heated? Why?
8. How many furnace pipes are concealed in partitions?
9. Locate a furnace pipe for heating the store room on the 3d floor.
10. How many flues are there in the chimney and what are their uses?

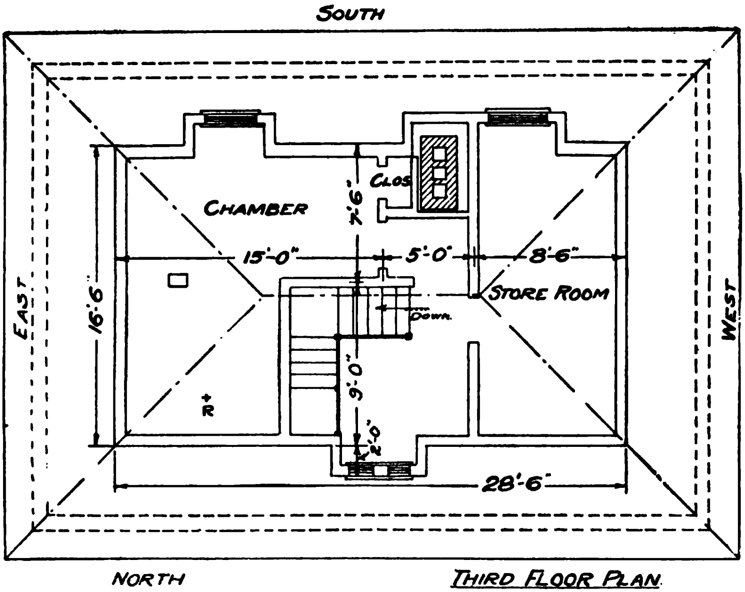


FIG. 12.—PLAN No. 2.

11. If the house is lighted by electricity, locate on the plans the position and number of lamps for
    - (*a*) All the rooms on the 1st floor
    - (*b*) " " 2d "
    - (*c*) " " 3d "
12. If the house is lighted by gas and electricity, locate all the outlets and number of lamps for
    - (*a*) All the rooms on the 1st floor
    - (*b*) " " 2d "
    - (*c*) " " 3d "
13. Has provision been made for a gas range and where?
14. Where would a stove be placed in the kitchen?
15. Is the position of the kitchen sink the best possible?
16. Indicate the doors and the way they would swing.

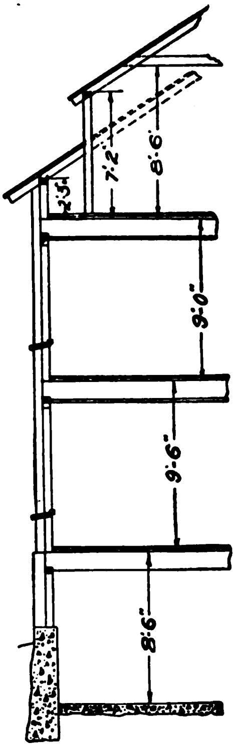


FIG. 13. — PLAN NO. 2.

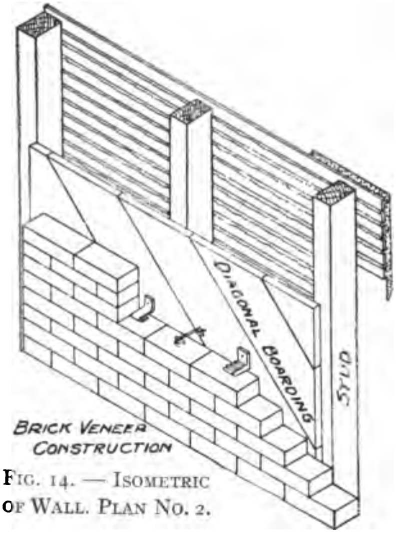


FIG. 14. — ISOMETRIC OF WALL. PLAN NO. 2.

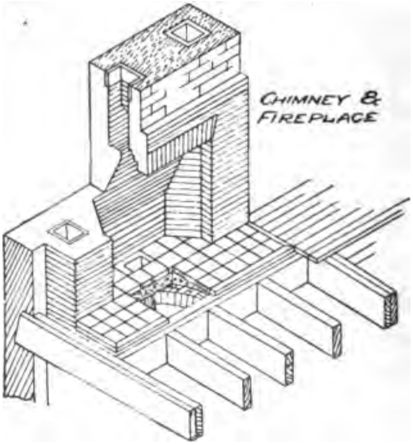


FIG. 15. — CHIMNEY AND FIRE PLACE. PLAN NO. 2.

17. Indicate the position of a bed and dressing case.

(*a*) In the S. E. chamber 2d floor (*c*) In the N. E. chamber 2d floor
(*b*) " S. W. " " (*d*) " N. W. " "
(*e*) In the 3d floor chamber.

18. Give the dimensions between the walls of
    (*a*) The dining room
    (*b*) The 1st floor hall
    (*c*) The N. W. chamber, 2d floor.

Note. — The outside walls being of a brick veneer construction are 10″ thick. (See detail drawing)

19. If the kitchen floor were covered with linoleum which is two yards wide, how many yards would be required?
20. How many steps must one make in going from
    (*a*) The first to the second story?
    (*b*) The second to the third story?
21. What must be the rise and run of the stairs from
    (*a*) The first to the second story?
    (*b*) The second to the third story?
22. What would be the distance from the floor to the ceiling at point *R* in the 3d floor chamber?
23. What is the height of the 3d floor rooms at their outer walls?

TOPOGRAPHICAL GRAPHICS

15. Topographical Map Reading. — The subject chosen is that of a United States Geological Survey of the Dedham District of Massachusetts, Fig. 16, pages 28-29. Maps of this character define the relative positions of towns and counties, the courses of rivers and locations of ponds, together with the characteristic features of the earth's surface as graphically described by a notation expressed by conventional signs. But of special interest to this study are the irregular curved lines known as contour lines which enable one to obtain the elevations of the surface of the earth, thus providing one with a third dimension, height.

At first there may appear to be no relation between a house plan and a topographic map, nevertheless they are designed to represent two features which are identical. First, to define the outline and relation of certain features which may be represented on a plane surface, and secondly, to represent elevation by means of a series of equidistant steps. In the house plan there are the treads of stairs which enable us properly to relate the several floors of a house, and in the topographic map a series of irregular lines, known as contours, lying in horizontal planes at equidistant heights. As in the case of the stair treads, we may determine the elevation of any section of the country by counting the number of contour lines lying between the desired level and some known base, provided the distance between the planes of the contours be known.

Thus we may obtain a general idea of the undulations of the earth's surface as well as the relation of its several features, such as towns, rivers, roads, etc., and by using a distinctive notation, or vocabulary, we may also read the character of the surface and determine whether it be wooded, swampy, or cultivated.

16. The Topographic Vocabulary. — The various signs which are used to indicate the character of the country shown by topographic maps, or the graphic vocabulary of this subject, are shown

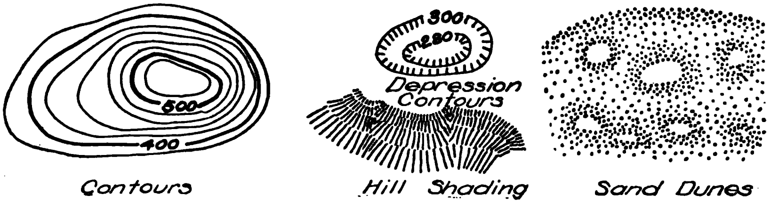


FIG. 17. — RELIEF

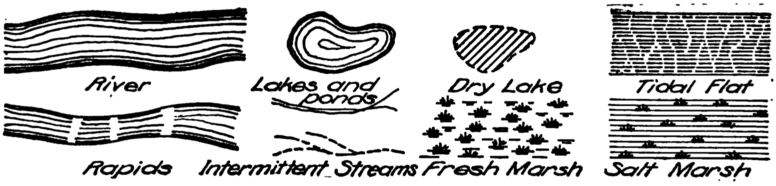


FIG. 18. — WATER

by Figs. 17 to 20, which illustrate the most common features of topography, but are by no means complete

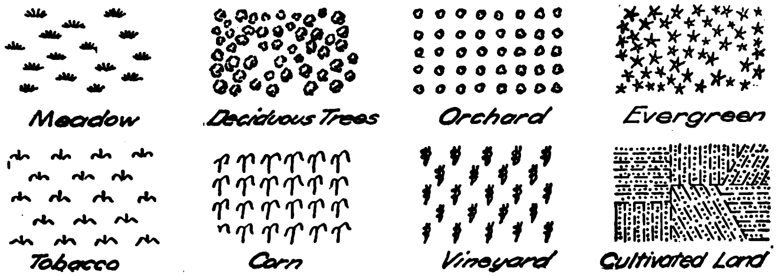


FIG. 19. — VEGETATION

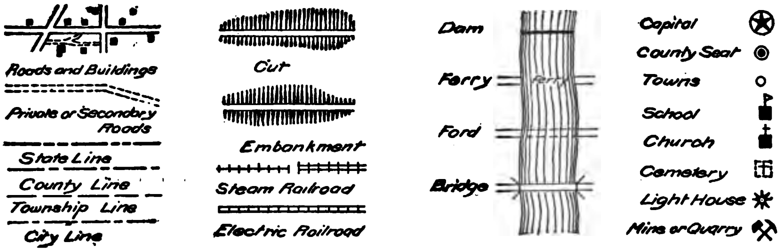


FIG. 20. — CULTURE

There are four classes of surface features which it is necessary to express by symbols. They are represented in Fig. 17 by **relief,** which indicates elevations and depressions, such as contour lines; Fig. 18, **water,** being the vocabulary for rivers, ponds, marsh, etc.; Fig. 19, **vegetation,** designating the vegetable growth; and Fig. 20, **culture,** which illustrates the character of the works of man, such as roads, buildings, and boundary lines.

17. Contours are imaginary lines on the earth's surface connecting points on the same level. When this representation is made on a map the lines are known as contour lines. If one were to walk on that part of the country indicated by a contour line he would not go up hill or down, but on a level. The shore line of a quiet sea is a contour. If the sea level were raised twenty feet the new shore line would be that of a twenty-foot contour. Since these contours lie in equidistant horizontal planes, the steepness of the surface which they represent will be indicated on the map by the nearness of the contour lines. If contour lines are equidistant on the map the surface is of uniform grade.

Suppose the irregular line *ACBD*, Fig. 21, to be the shore line of an island, and the lines drawn within this area to represent twenty-foot contours, then will the elevation of the highest point be more than eighty feet, but not over one hundred feet, since there is not a fifth contour line. If the summit be approached from point *A* along the line *AB* the distance between the contours lessens, indicating an increase in the grade as one rises, but on passing the summit and descending on the opposite side, the equidistant contours indicate a uniform grade. This is shown by the lower view which is a section on the line *AB*.

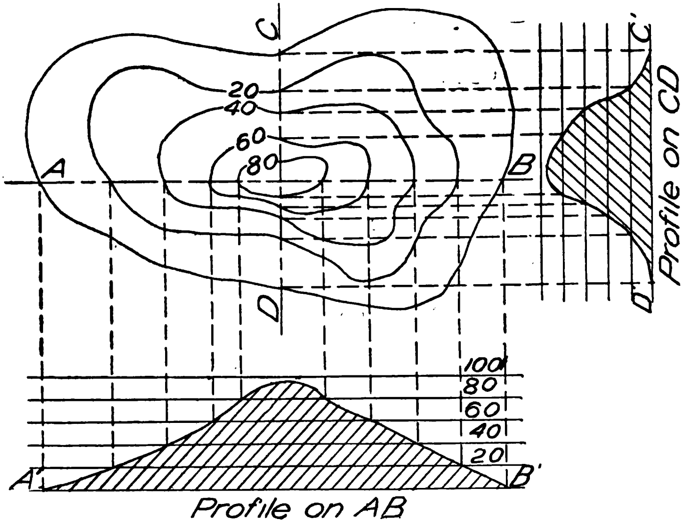
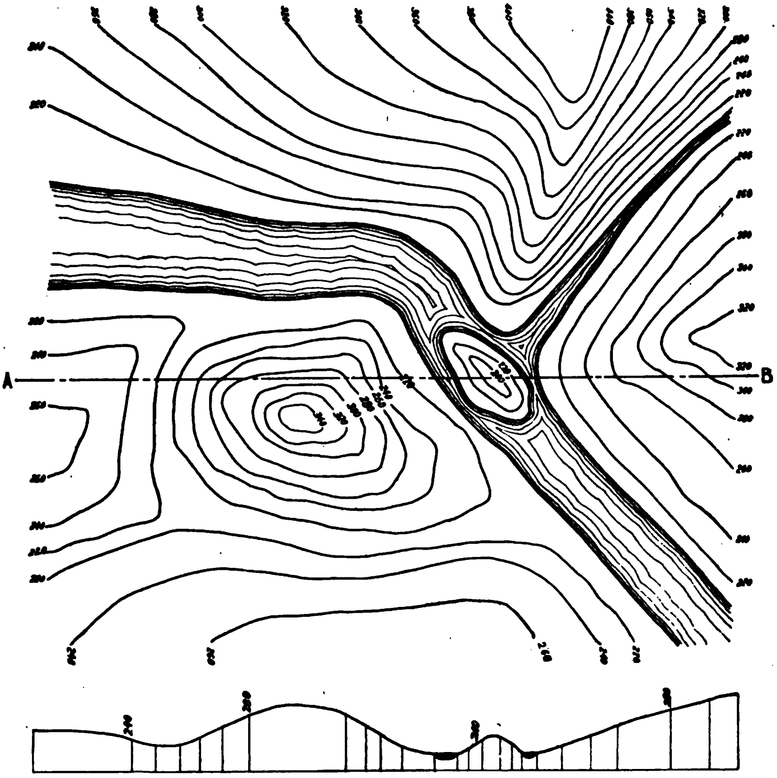


FIG. 21. CONTOURS

Such a view is known as a **profile.** Because of the necessity of exaggerating the variations in levels shown in a profile, the vertical scale is commonly made greater than the horizontal scale.



PROFILE A-B

FIG. 22. — CONTOURS AND PROFILE

The horizontal planes on which the contour lines are drawn are measured from a known base, or datum plane, which is usually at mean sea level. The line which represents this plane on a drawing is the datum line. See *A'B'* of Fig. 21.

Fig. 22 represents the contour lines of a hilly country through which a river runs having an island in it. A profile on *AB* is shown at the lower part of the figure.

18. Hachures. — Relief is also indicated on maps by means of short lines known as hachures, as shown by Fig. 23, which is a map of the same surface as that of Fig. 22. These short lines are drawn to indicate the path that water would flow down the slope represented, and thus suggest the direction of the slope, but they do not serve the purpose of vertical measurements as do the contour lines.

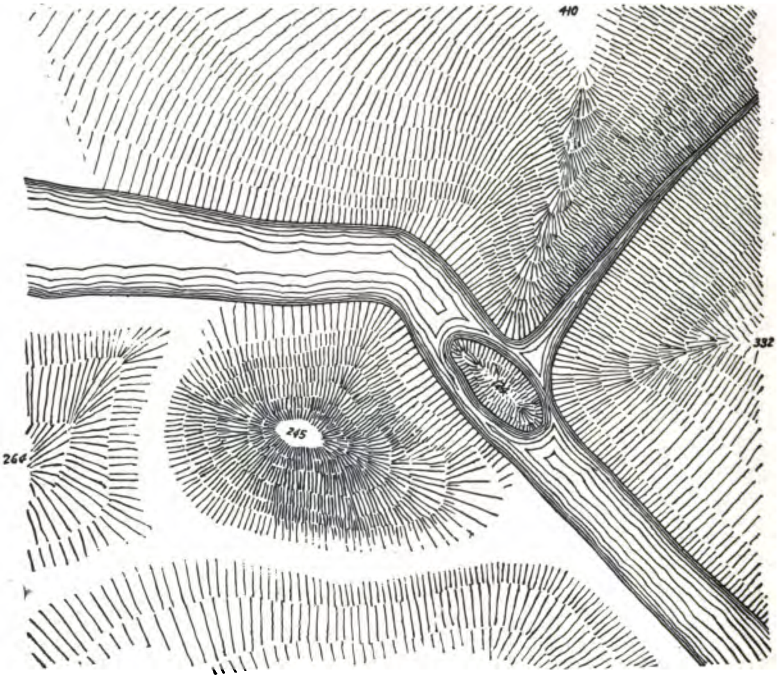


FIG. 23. HACHURES

Fig. 24 is a plan of an estate which illustrates the use of contours in studying the location of a house and the grading necessary to the proper treatment by the landscape architect.

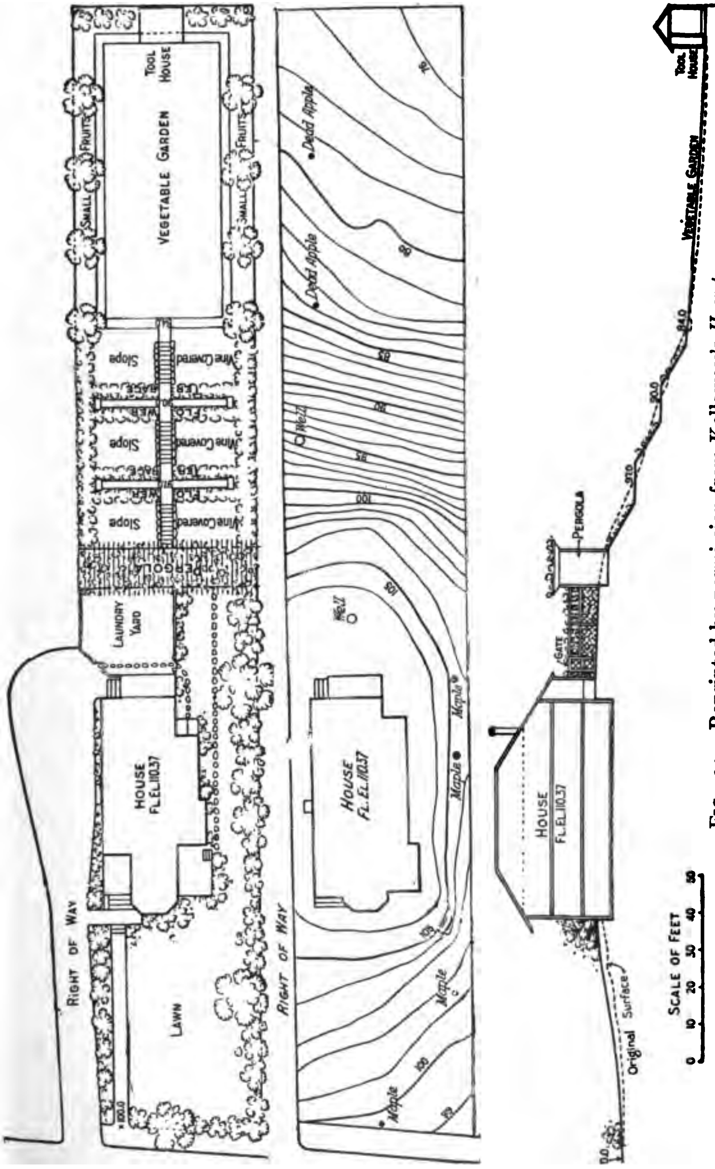


FIG. 24. Reprinted by permission from Kellaway's *How to Lay out Suburban Home Grounds*, published by John Wiley & Sons, Inc.

19. Geological Survey Maps. — Fig. 16, pages 28-29, is a part of one of the standard maps published by the Government. These maps are reproduced by photo-lithography from very accurate surveys and the series now includes sixty per cent of the United States. The unit size of the publication is a sheet 16½″ × 20″, the mapped area representing from 210 to 226 square miles. The most common scale is about one inch to one mile (1 inch = .9864 mile) or 1 to 62,500. The contour intervals are 20 feet. These maps can be purchased at many bookstores and stationers. The Government price is 10 cents each for the unit size of 16½ × 20″. They are useful for topographical reading exercises and are of great value in acquainting oneself with the details of any section of the country.

20. A Summary of Principles Regarding Contours. — All points in the same contour line are at the same elevation.

Contours do not cross each other. When they run together they indicate a vertical surface.

Every contour closes upon itself or disappears at the border of the drawing.

Equally distant contours show uniformly sloping ground. The closer together the contours, the steeper the surface.

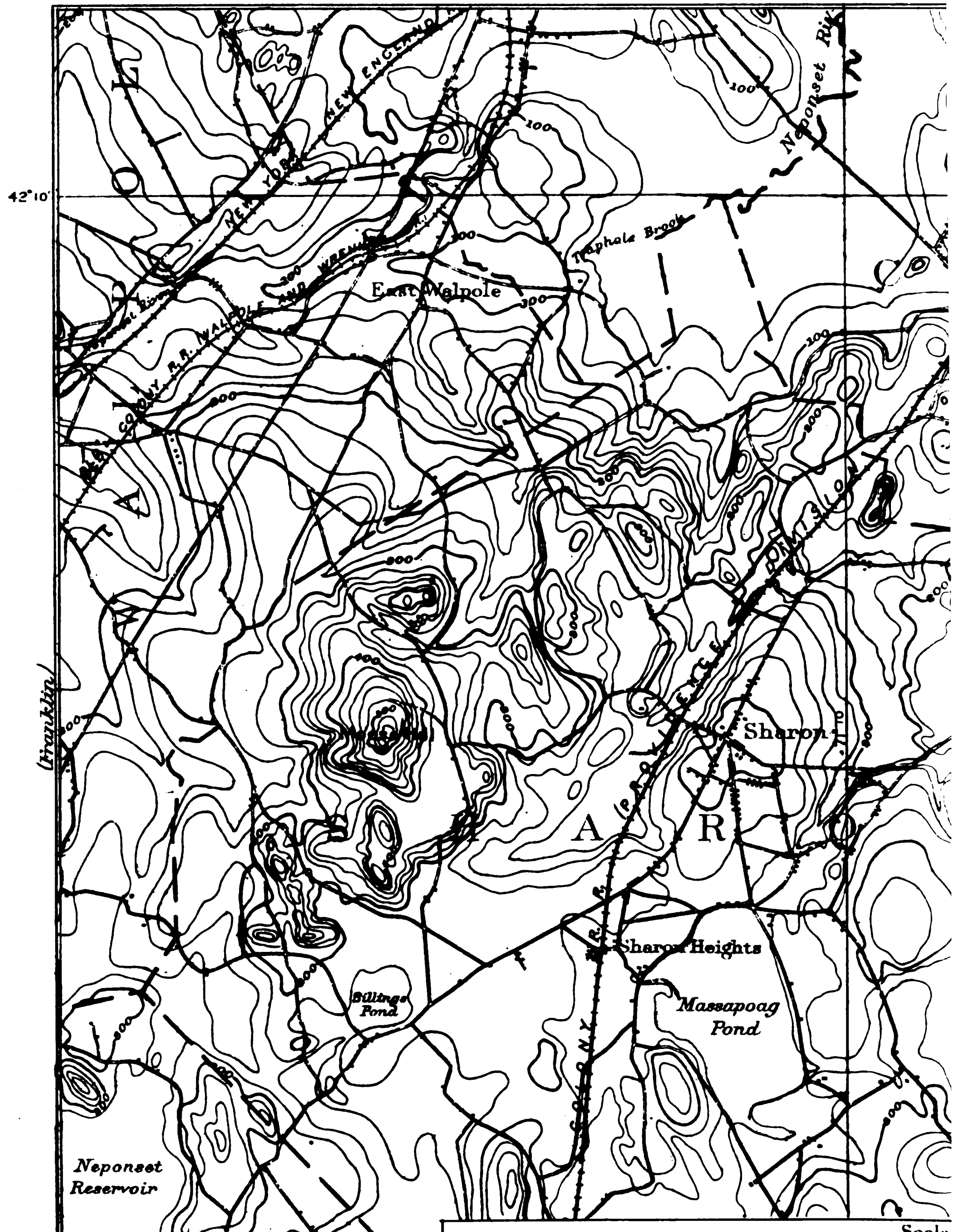
The steepness of the surface, or angle, shown by contours is expressed by the following ratio

$$\frac{\textit{Vertical distance between contours}}{\textit{Horizontal distance between contours.}} = \textit{Angle of Slope}$$

Questions on Topographical Map Reading

Subject: Dedham District of Massachusetts, Fig. 16, pp. 28-29.

1. What is the scale of the map?
2. Would a change in the scale of this map make any difference to the details?
3. How many miles are represented by 2¾″ on the map?
4. What is the highest elevation in the town of Sharon?

42°10'
42°5
(Franklin)
East Walpole
Traphole Brook
Neponset Riv
NEW YORK NEW ENGLAND
WALPOLE AND WRENTHAM
OLD COLONY R.R.
Sharon
Sharon Heights
Massapoag Pond
Billings Pond
Neponset Reservoir
100
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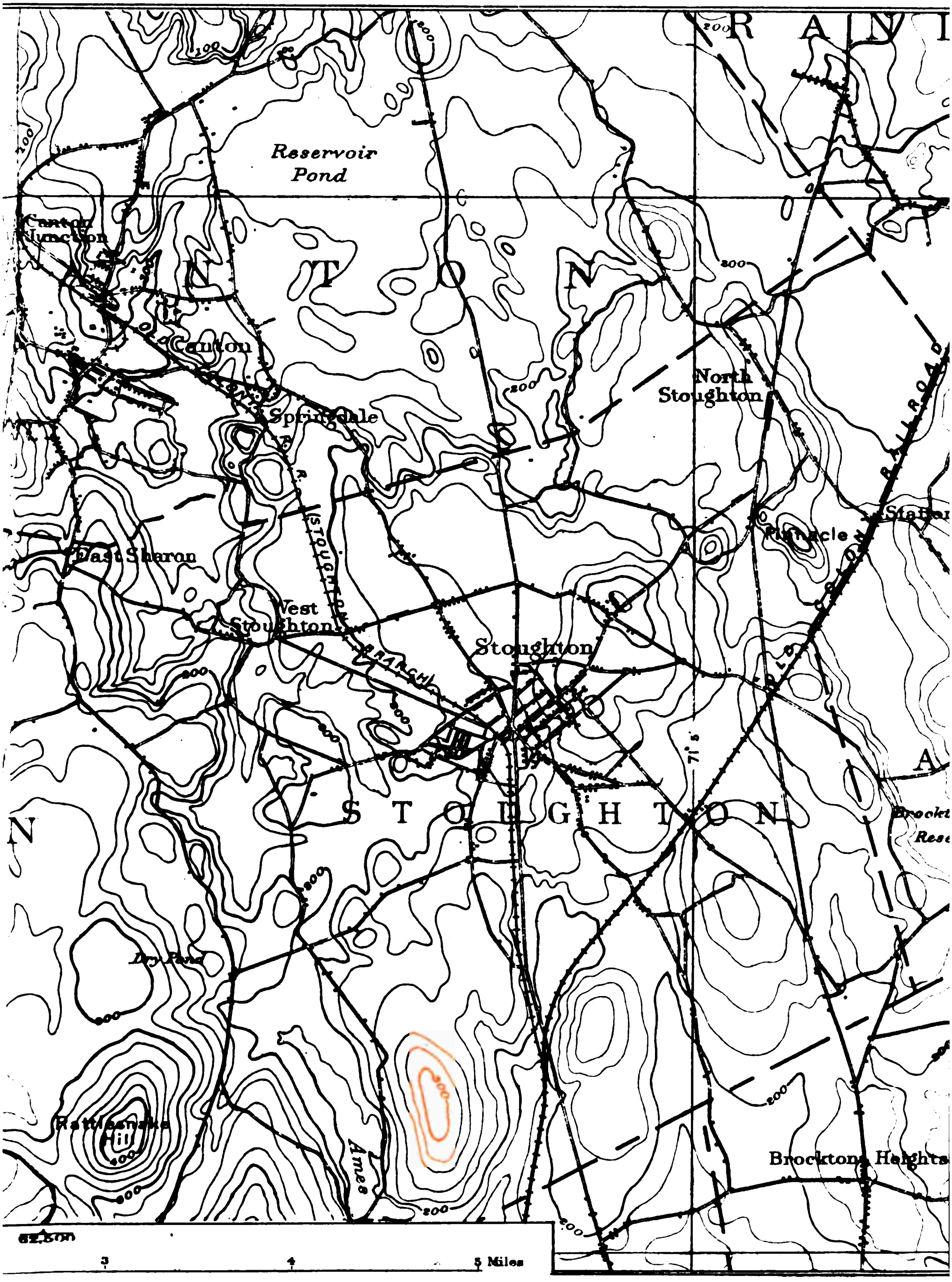
U.S. GEOLOGICAL SURVEY
Contour Int



DEDHAM SHEET Fig.16

5. What is the highest elevation in the town of Stoughton ?
6. What is the elevation of Reservoir Pond?
7. What are contour lines?
8. Is the shore line of a quiet pond a contour line?
9. Is the shore line of a river a contour line?
10. What is a datum line?
11. What is the mean datum line to which contour elevations are usually referred?
12. What does an equal spacing of contours represent?
13. If contours are very close, what does it indicate?
14. If contour lines coincide what does it indicate?
15. Can contour lines cross? Give reason.
16. Use the straight edge of a strip of paper and with a pencil measure the distance from East Sharon to the ford at Ames Pond.

NOTE. — In measuring distances on curved roads for which profiles are required, it is best to use a strip of paper on which the crossing of the contours can be marked. The scale for elevation should be such as to clearly define the variations in grade.

17. Draw a profile on longitude 71°5′ from Lat. 42°10′ South.
18. Draw the profile of the railroad from Canton Junction to Stoughton.
19. Draw the profile of the highway from Stoughton to Sharon.
20. Draw the profile of the highway from East Walpole to Billings Pond.
21. If the water in Reservoir Pond should flood the swamp land to the East, what would be its outline, supposing it to be damned at the roadway on the Western end.

PICTORIAL GRAPHICS

21. Perspective Reading. — The reading lessons which have preceded this were graphic representations of features which could be described quite well by two dimensions, although a third dimension, height, was suggested by the stairs of the house plans, and by the contour lines of the topographic maps. In order to express more complex ideas through the medium of graphics, it is necessary to use three dimensions, and perspective enables us to do this in a simple manner when exact details are unnecessary and the labor of writing graphics need not be considered. It will serve also, by observation and practice, as an introduction to a series of studies which will explain certain underlying principles in the grammatical construction of the graphic language.

Every one is accustomed to reading perspective representations because they are of the same character as those made on the retina of the eye, or on the sensitized photographic plate of the camera. Nevertheless, it requires considerable skill to produce this effect without the aid of photography or other mechanical devices. One is easily convinced of this by attempting to make representations of such familiar objects as tables or chairs, and if one has had no previous training in accurate observation and the recording of it by what is known as freehand drawing, the result will probably be a distorted representation. This is generally due to certain exaggerations given to vertical dimensions, as well as an attempt to represent things as they really are instead of as they appear. At present we are not so much concerned with the making of perspective drawings as with an understanding of certain principles that will serve to elucidate other and more practical methods of graphic representation.

22. The History of Perspective Drawing.—Although primitive attempts to express ideas graphically must have been made in the earliest age of man, the scientific delineation of objects, and especially the development of graphic language, is of comparatively recent growth. The delineation of the human figure and that of animals is found in records of the most ancient civilization, but it was in ouline only and with no suggestion of the rounded form. The early landscape drawings expressed but slight suggestions of depth or distance, and it was not until the period of the Renaissance, which was about the time of the discovery of America, that any understanding of the theory was made known. Although the early Greek mathematicians had investigated the mathematical principles of perspective, the graphic application of the theory was not made until the 15th century.

Leonardo da Vinci (1452–1519), one of the great artists of that period, and a greater scientist and engineer, wrote a treatise on painting which included a thorough development of the theory of perspective in sufficiently good form and detail to be used at the present day as a text on that subject. The principles of the new science were rapidly adopted and applied to the paintings of that day by Michael Angelo, Rafael, and other great artists of the Renaissance who introduced many architectural details and landscapes into their masterpieces with apparent pride in displaying the newly found principles.

It is interesting and instructive to study some of the works of the old masters of this period and to observe the influence which a knowledge of perspective made on the composition of their pictures. Two cases are illustrated by Figs. 25 and 26.

This early development of the theory of perspective is remarkable in that the geometry of projection on which the theory is based is largely attributed to Gaspard Monge, (1746–1818), a Frenchman who wrote the first treatise on descriptive geometry which also included the subject of perspective and shadows.

In Fig. 25, page 32, which is a copy of a painting by Bernardino Pinturicchio (1454–1513), the artist probably found some difficulty in conforming strictly to the laws of perspective and resorted to the use of two horizons which one may easily detect with an understanding of the following four articles. This artist was painting within the period of Leonardo da Vinci's teachings.

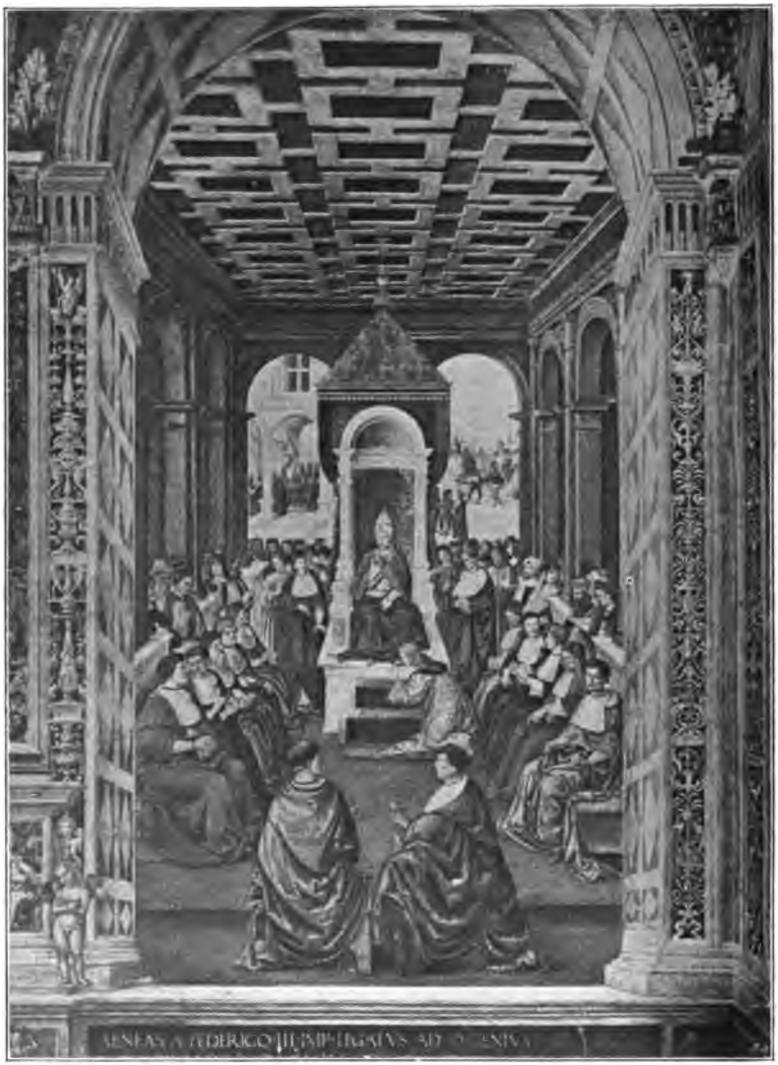

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FIG. 25. A PAINTING BY PINTURICCHIO (1454-1513)

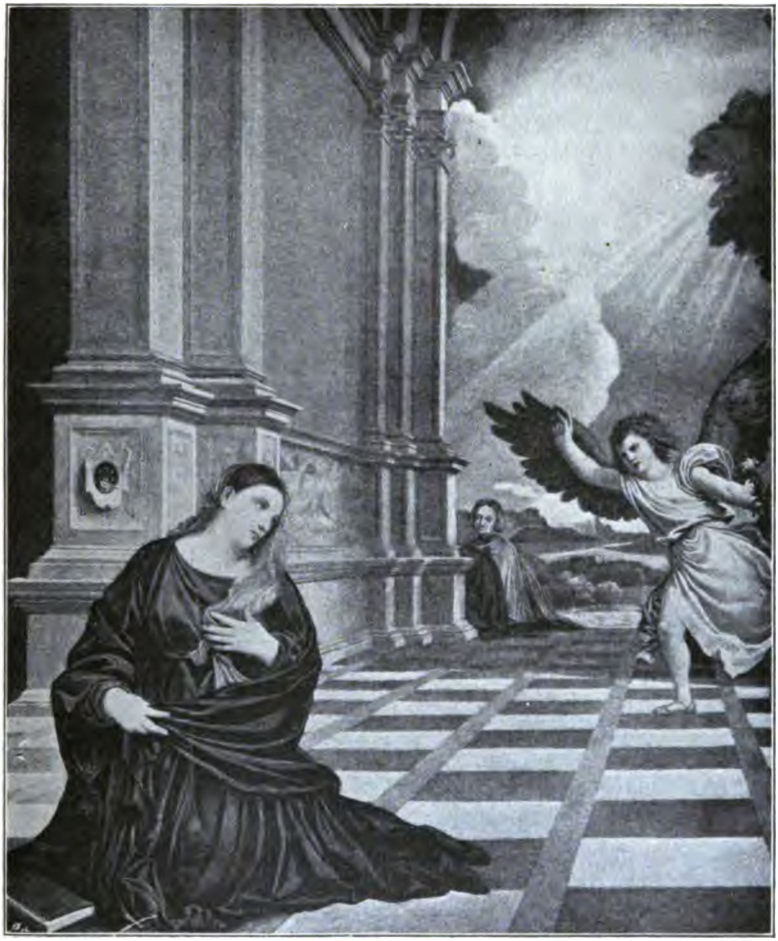

FIG. 26. THE ANNUNCIATION BY TITIAN (1477-1576)

In Titian's painting of the Annunciation, Fig. 26, there is an interesting application of perspective to the architectural details of the picture. After reading Arts. 24 to 26 inclusive, test this drawing for its accuracy in perspective drawing.

23. Appearance of Parallel Lines. — Every one is familiar with the appearance of a railroad line and the apparent convergence of the rails as one views the track from between the rails, or a little to one side of them. If there is no curvature in the track the rails appear to approach each other, and if the surface is level the rails will appear to meet in a point on the horizon, as in Fig. 27.

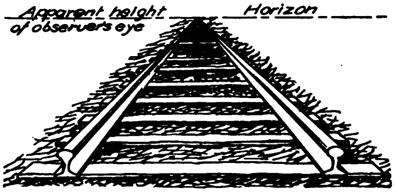

FIG. 27

Again, if one views a street from between rows of parallel buildings, as in Fig. 28, all the horizontal lines will appear to converge to a point, save when they are parallel to the plane on which the picture is made. This latter case is illustrated by the fronts of the buildings in Fig. 28, on which all the horizontal lines are parallel.

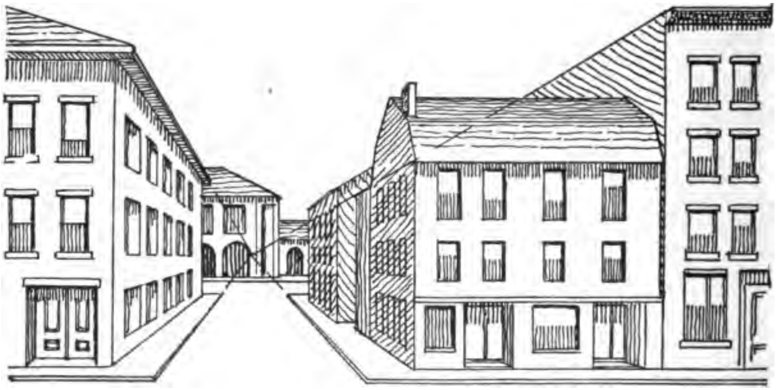

FIG. 28

24. The Horizon in a picture is the line in which all horizontal lines and planes appear to vanish, or meet, and is always on the same level as the eye. When looking out on the ocean it is the line in which the water and sky appear to meet. It matters not whether the observer is on the ground or in a balloon, the horizon will appear to be on a level with his eye. It is possible, therefore, to determine the height of an observer from a photograph or other perspective representation by determining the position of the horizon and obtaining some unit of measurement, such as the height of a building.

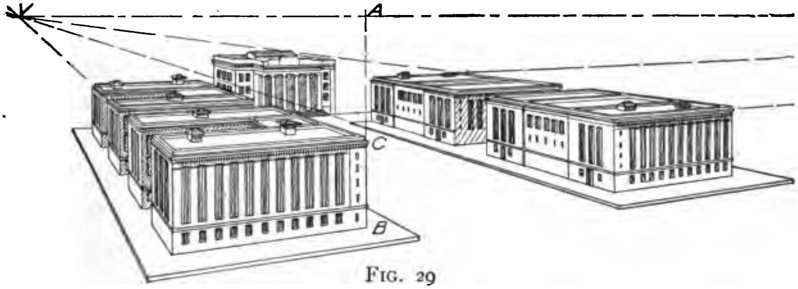

FIG. 29

Fig. 29 illustrates these principles. It is a view of a group of buildings which are parallel to each other, but none of the faces of the buildings are parallel to the picture plane. Because of this latter fact, there are two vanishing points for the horizontal lines, one to the left at *V* and a second one to the right at a considerable distance beyond the limits of the picture. This second point could be determined by extending any line of the front face of the buildings until it intersects the horizon line drawn through *V*. Inasmuch as it is possible to see the roofs of the buildings, it must be that the observer is at an elevation higher than the roofs. If the roofs had been on a level with the eye, they would have appeared as one horizontal line coinciding with the horizon. Suppose a front corner of the left hand building *B*, to be extended to the height of the horizon as at *A*, it will enable us to determine the height of the view point, or the observer's eye, since it would represent one point in the roof of the building if at the height of the eye. In this case, it is a little more than 2¼ times the height of the building *BC*, which latter being known would serve as a unit for measurement. Any other corner of the buildings might have been used for this measurement, but in such case the unit of measurement and line to be measured would be proportionally changed.

The student should test these principles by making the necessary lines and measurements on photographs and prints, many interesting examples of which may be found in the pictorial sections of the Sunday papers.

25. The Vanishing Line of Planes other than Horizontal.—Figs. 30, 31, and 32 are the perspective representations of a box with a cover in different positions. The upper surface of the box and its cover being horizontal, as in Fig. 30, its lines will vanish in the real horizon, which is marked the first horizon. In Fig. 31 the cover has been lowered and its edges vanish in a new line indicated as the second horizon, but it must be observed that the new vanishing point V_2 lies directly below the vanishing point, V_1 of horizontals. Similarly, by raising the cover, as in Fig. 32, a third horizon is established, and all surfaces parallel to this position of the cover will vanish in this horizon.

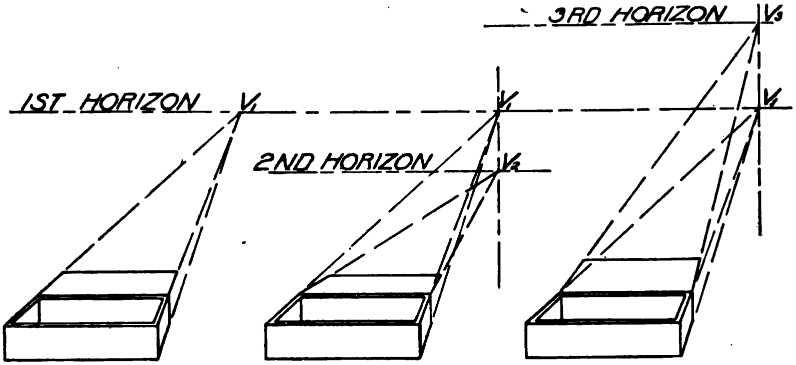

FIG. 30 FIG. 31 FIG. 32

In whatever position the cover may be placed, its right and left hand edges will vanish somewhere in the line $V_1 V_2$ of Fig.

31, which is the vanishing line for the plane of the right and left hand edges of the box.

Note the application of this principle to the drawing of the gambrel roofed house, Fig. 33. Also the method of obtaining the position of the ridge pole.

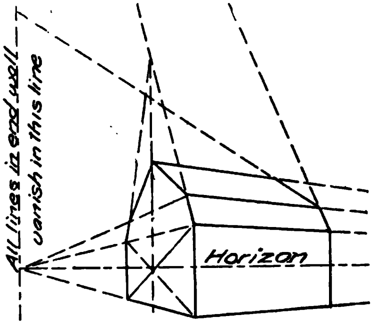

FIG. 33

26. Measurement by Diagonals. — Inasmuch as the perspective representation of lines does not maintain their true proportion, unless they chance to be parallel to the observer, it is not possible to use a scale for the direct measurement of perspective drawings, but there are geometrical relations which simplify certain classes of measurements, one of which is by diagonals.

Fig. 34 represents an arched passage covering two rectangular surfaces, *ABCD* and *CDEF*. These surfaces being of the same size, the diagonals of the rectangles will be parallel in reality, and their perspective will appear to meet in the horizon at *V*. Therefore, the first rectangle having been assumed, the second is determined by drawing the diagonal *BC* until it intersects the horizon at *V*, and through this point drawing the diagonal of the second rectangle, *DV*, intersecting the extended side *AC* at *E* through which the line *EF* is drawn parallel to *AB*, or vanishing at the same point.

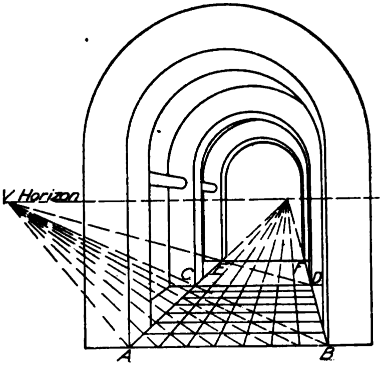

FIG. 34

Similarly, vertical surfaces may be reproduced as shown in Fig. 35, which represents three buildings of the same size and shape. Note the method of obtaining the center line of the ridge pole by the intersection of the diagonals. The vanishing point of diagonals was assumed, as was also the face of the first building, *BCDE*, together with the height of the ridge pole.

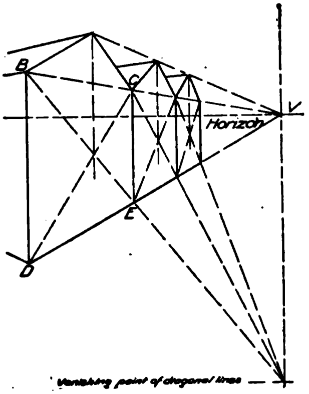

FIG. 35

27. The Perspective Drawing of Stairs. — Fig. 36 illustrates an application of most of the principles involved in the foregoing articles and the reasons for the construction lines should be studied.

In making this drawing, no pains were taken to make the second flight of stairs of the same "run" as the first flight, as it would have involved methods of measurement which have not been considered. Indeed, the practical methods of making perspective drawings and the systems of measurement, do not belong to this treatise.

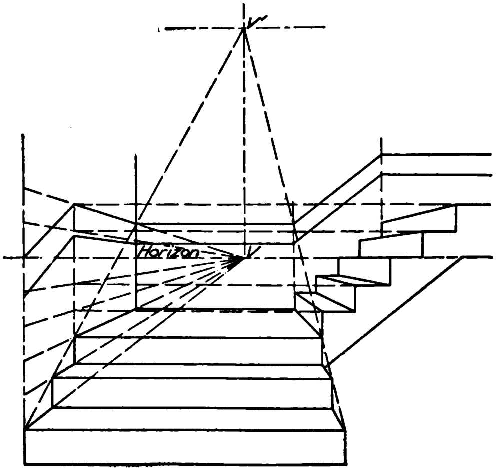

FIG. 36

28. The Perspective Drawing of a House. — Fig. 37 is suggestive of methods to be used in applying the principles of diagonals to the perspective of a house, and the order of drawing the lines may be as follows: Having determined the relation of the horizon to the height of the house, and the position of the nearest corner, *LO*, assume the vanishing points of horizontals parallel to the front and side of the house and draw the outline of the base *ORTS*, in the center of which is the chimney, *ABCD*, which in this case has one dimension equal to the width of the door frame.

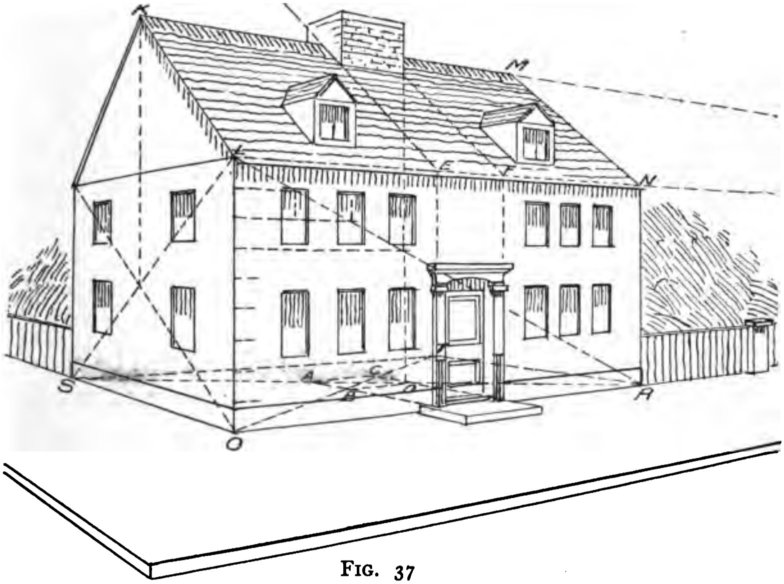

FIG. 37

The height of the walls, *OL*, may be assumed as well as the ridgepole, *KM*, and the perspective of the chimney, which is directly above its position as outlined on the base, may then be determined. The intersection of the chimney with the roof is determined by continuing the perspective of its edges, *AB* and *CD*, to intersect the front line of the house, then continuing them vertically to intersect roof at *E* and *F*. The lines drawn from these points parallel to the gable end will vanish at the same point as *KL* and *MN*, which will be directly above the vanishing point of horizontals that are parallel to the end of the house.

The number of windows being assumed, they may be spaced as follows: Divide the vertical edge, *OL*, into as many parts, plus one, as there would be windows if evenly spaced on the front of the house. In the case illustrated, there would have been eight. The lines drawn from these points to the vanishing point of horizontals at the right will intersect the diagonal *LR* at the center of the windows. Minor details have been sketched.

29. Fundamental Principles of Perspective.—

1. The picture, or perspective, of parallel lines appears to meet in a point unless the lines chance to be parallel to the plane on which the picture is made.

2. All systems of parallel lines which lie in horizontal planes appear to meet in a horizontal line which, in a level country, or at sea, is the horizon.

3. The horizon is always on the same level, or horizontal plane, as the observer's eye.

4. All lines parallel to the plane of the picture will be accurately represented in perspective by lines having the same relative position and direction.

30. The Application of Perspective to Topography.— Perspective representations have many useful applications aside from pictorial interpretation. Since perspective representations are capable of being produced by geometrical means, it is possible to reverse the process and from the perspective representation produce an exact graphic presentation by other systems.

One of the most interesting and remarkable translations of perspective into topographic graphics was made by the Canadian Government in producing the accompanying contour map entirely from four photographs. Two of these photographs are shown by Figs. 38 and 39, and the contour map by Fig. 40.

The geometrical process by means of which this result was obtained lies beyond the scope of this elementary treatise, requiring an understanding of descriptive geometry, the elements of which are considered in Chapter II.

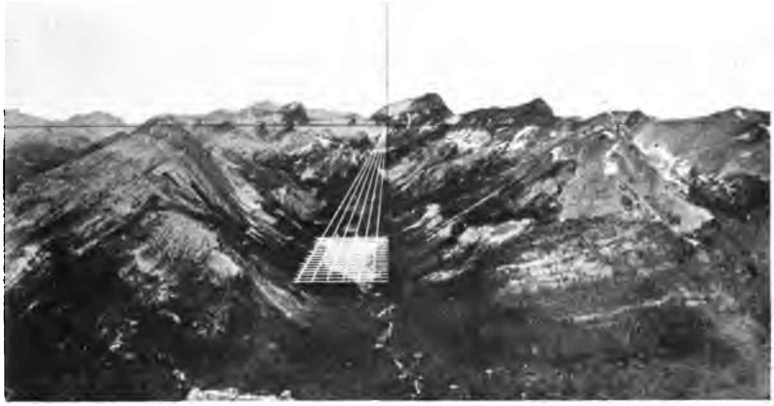

FIG. 38. FROM C. HECTOR STATION

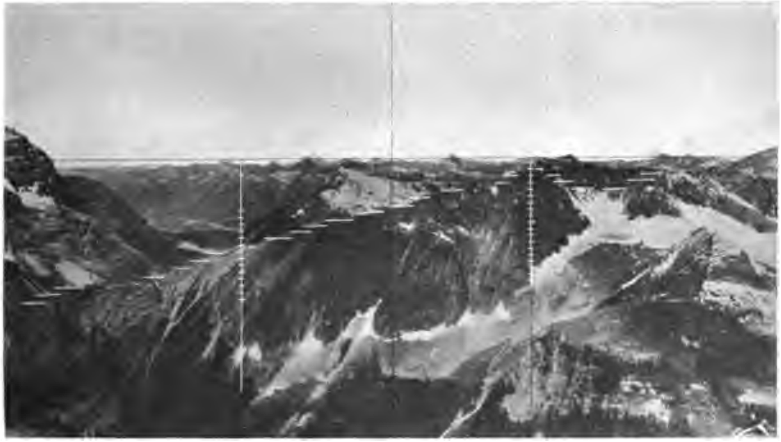

FIG. 39. FROM 2 HECTOR STATION
Reprinted by permission from *Photographic Surveying* by E. Deville, Surveyor General, Canada

This method of obtaining contour lines without the labor and greater expense of making the ordinary survey of the country was devised by Laussedat in 1849, but it was first extensively employed by the Canadian Government which, previous to 1892,

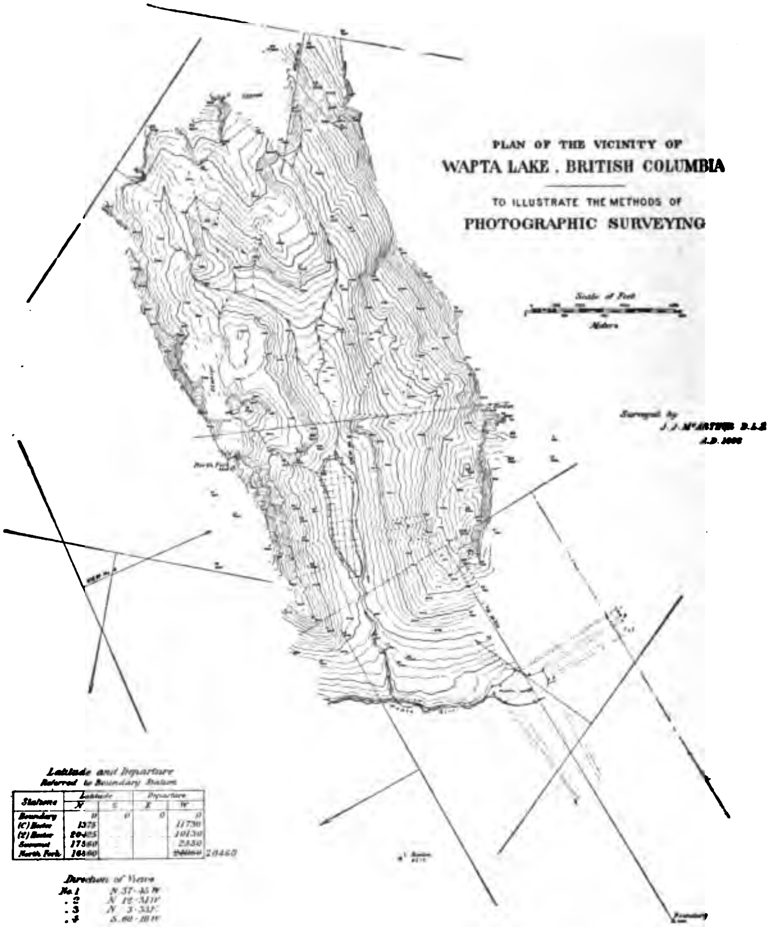

FIG. 40. CONTOUR MAP OF THE COUNTRY ILLUSTRATED BY FIGS. 38 AND 39
Reprinted by permission from *Photographic Surveying* by E. Deville,
Surveyor General, Canada

made a survey of the Rocky Mountains in the vicinity of the Canadian Pacific Railway covering about 2000 square miles, and in 1893 and 1894 surveyed about 14,000 square miles.

Fig. 41 illustrates the latest application of photography to surveying, it having been made from an air plane by the American Air Plane Service Corporation. This method of making photographic maps does not introduce the problems of perspective involved in the Canadian Survey previously described as the photograph was taken from an air plane directly over the space photographed so that the reduction of all the lines and areas is uniform. It also enables the surveyor to present many features not possible in the ordinary survey, beside reproducing the exact conditions prevailing over the entire area at the instant of photographing.

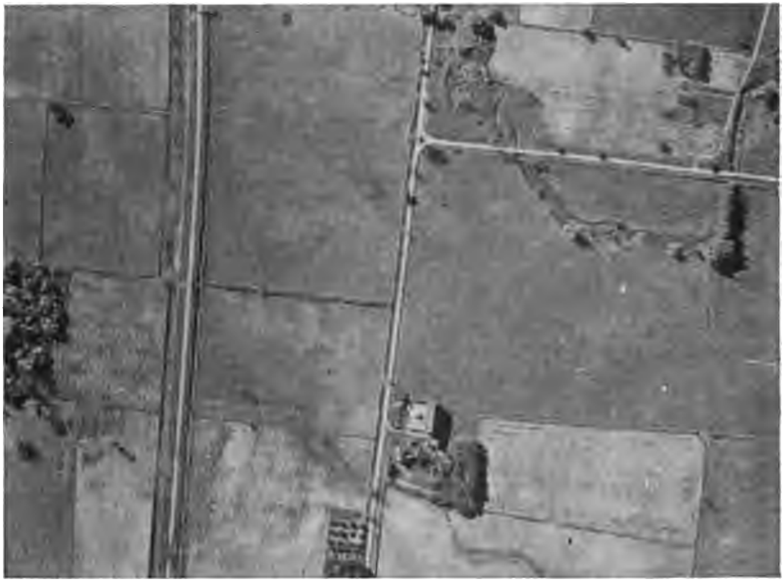

FIG. 41. AERIAL SURVEY
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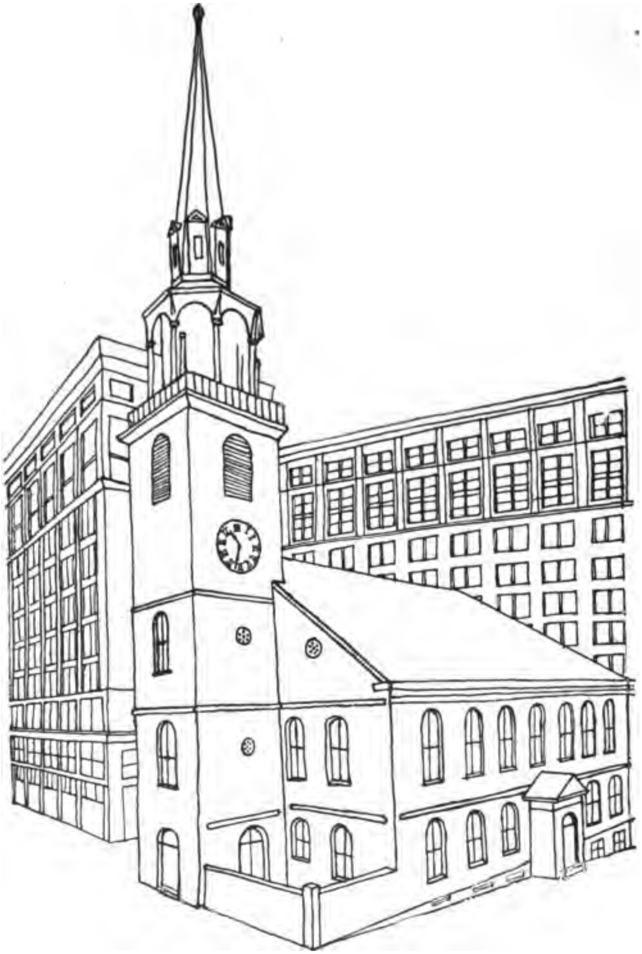


PERSPECTIVE PROBLEM 1

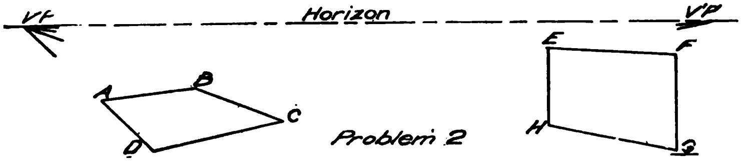
Problems in Perspective Reading and Expression

These problems are suggestive of the character of those which may be found on every hand in books, illustrated papers, postal cards, etc.

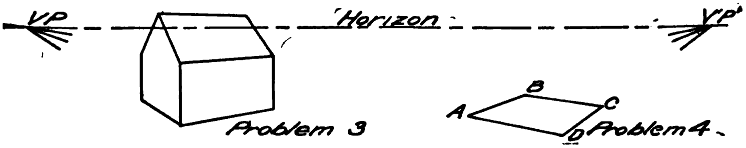
Problem 1. — Make an outline tracing of the above, omitting doors and windows, and on the tracing determine the following: —

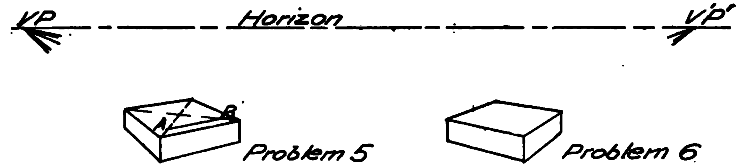
1. The horizon.
2. The vanishing points of the horizontal lines of the church.
3. The vanishing points of the gable ends of the roof.
4. Are the buildings to left and rear of the church parallel?
5. Trace the outline of the church with the tower removed, the tower being in the center of the front of the church.
6. Which is the higher, the square tower or spire resting on it?

Problems 2 to 6 should be drawn about double the size of the cut, similar to those illustrated, but in true perspective.



Problem 2. — *ABCD* and *EFGH* are the perspectives of horizontal and vertical squares, the sides of which vanish at *VP* and *V'P'*. Divide them into sixteen equal squares.





Problem 3. — Draw the perspective of a building similar, adjoining, and to the right of the one assumed.

Problem 4. — On an assumed base, *ABCD*, draw a right pyramid.

Problem 5. — Assume a square base and draw a square column five times the height of the base, having *AB* for one of its edges.

Problem 6. — On the assumed block draw a second one of twice its height and make the upper surface the base of a pyramid of four times the height of the lower base.

31. Pictorial Methods Other Than Perspective. — Because of the difficulty in making perspective drawings, and the inability to obtain direct measurements from them, several modifications of perspective are used. These substitute representations do not appear quite natural as compared with perspective drawings since a slight distortion is suggested, but inasmuch as they present less difficulty in execution, and permit of measurement by a scale, they are very useful in cases where a perspective effect is desirable and the labor of drawing is to be avoided.

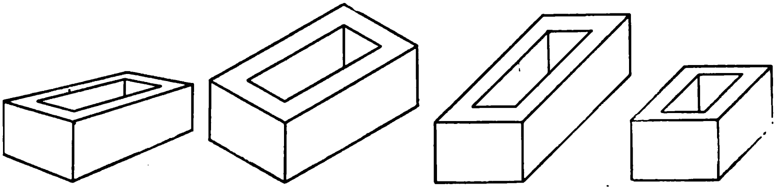

Perspective Isometric Oblique Cabinet

FIG. 42. PICTORIAL REPRESENTATION

Fig. 42 illustrates a hollow rectangular block drawn in perspective and also by three substitute methods which are in common use, easily constructed, and may be measured. The first, or isometric representation, is the most useful and will be described in detail.

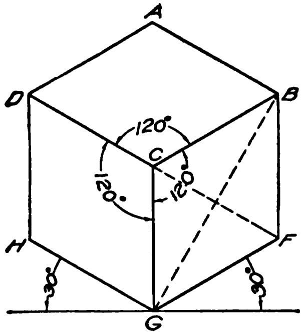


FIG. 43

32. Isometric Representation. — Fig. 43 is an illustration of a cube by the first of the systems of modified perspective, known as isometric. It will be observed that the lines *DA* and *CB* do not converge as they would in perspective, but are parallel, and moreover, all the lines of the cube are of equal length instead of being foreshortened as in perspective. This enables one to measure these lines, or any lines parallel to them, because they have been drawn in their true length, but other lines will be more or less distorted. Thus we know the diagonals of a square to be equal, but this is not true of *CF*, and *BG*, the isometric of the diagonals of the square face of the cube. Again, it may be said that although *CBFG* is the representation of a square, the angles are not right angles, and thus we observe that one cannot rely on the measurement of angles in isometric. Nevertheless, if care be used in measuring only such lines as are parallel to *CB*, *CD*, and *CG*, quite complicated drawings can be made and read with ease.

It must be observed that *CB*, *CD*, and *CG* make equal angles with each other, *CB* and *CD* being drawn at 30° with a horizontal. These lines are known as **isometric lines,** or **isometric axes,** and no correct measurements of the drawing can be made that are not parallel to one of them.

33. To Make an Isometric Drawing. — Isometric drawing is so useful, so easily made, and such an aid in giving expression to one's ideas in the elementary stages of the study of graphics, that it is important for the student to acquire some facility in expressing himself through this medium. The solution of a few problems will suffice for this understanding.

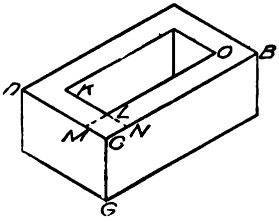


FIG. 44

Suppose it be required to make the isometric representation of the object represented in Fig. 44. Beginning with the front upper corner *C*, draw the three isometric lines *CB*, *CD*, and *CG*, of the required length, *CB* and *CD* being drawn at angles of 30°, and *CG* as vertical. The remaining edges will be parallel to them. To obtain the inner surface, lay off *CN* and *CM* equal to the distances between the parallel lines *KL* and *DC*, and *LO* and *CB*, which will determine the corner *L*, from which the parallel lines of the inner surface may be drawn.

34. Non-Isometric Lines. — Since all objects do not consist of rectangular faces, the edges of which would be lines parallel to the isometric axes, it is necessary to draw such non-isometric lines, locate points, and draw curves.

Fig. 45 is the perspective drawing of a figure of which it is required to make an isometric representation, the dimensions being given. Proceed as follows in making the drawing shown in Fig. 46:

Draw *AD* 4 inches long at an angle of 30°, and *AB* 2½″ long, at an angle of 30° in the other direction, completing the rectangle of the base as shown by the dotted lines. As the slant edges *AE*, *BF*, etc., are non-isometric lines they cannot be measured, and it will be necessary to find points directly under their extremities, *E*, *F*, *G* and *H*, at which perpendiculars must be drawn of the required height, 1½″. Since the upper base is 2″ shorter and 1″ narrower than the lower base, lay off half of this difference in length, *A N*, and from *N* one-half the difference in width, thus obtaining the point *L* from which the vertical height *LE* may be drawn. In like manner, the other corners of the upper base may be obtained and connected to complete the rectangle. It will simplify the drawing, if after having obtained the point *E*, the upper base be drawn from this point as was the lower base from point *A*.

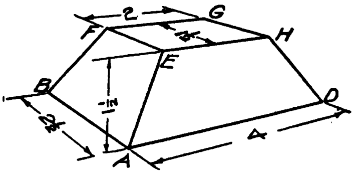


FIG. 45

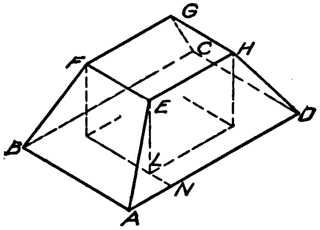


FIG. 46

Any non-isometric figure may be drawn by enclosing it within a rectangle from the sides of which all the points may be located — see Fig. 47, which is the isometric drawing of a pentagon.

Although any object may be represented in isometric, this system is best adapted to objects made up of rectangular surfaces having few curves and which may be fully explained by an exterior view.

35. To Locate a Point and Draw Angles in Isometric.— Fig. 48 is the drawing of a square surface on which a point *M* and certain angles have been designated, and it is required to make the isometric representation of them as in Fig. 49.

To locate point *M* draw *M N* perpendicular to *GF*, and since *GN* and *MN* will be parallel to the isometric axes, they may be laid off to scale in Fig. 49, and *M'* will be the required position in isometric.

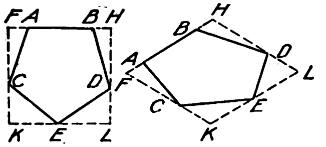


FIG. 47. NON-ISOMETRIC LINES

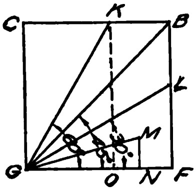


FIG. 48

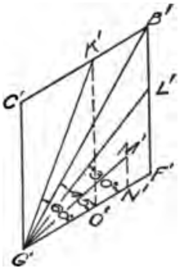


FIG. 49

In like manner, the several angles designated in Fig. 48 may be obtained by laying off two sides which are parallel to the isometric axes.

36. The Isometric of a Curve. — Having determined the method of finding any point in isometric, as described in Art. 34, it is possible to draw a curve by determining its successive points. The curve shown on the isometric of the square *C'B'G'F'* Fig. 51 is the isometric of a circle (an ellipse) which may be obtained by determining a succession of points from its true shape as shown in Fig. 50, and as previously described, or by finding points *T'R'*, *L'S'*, the major and minor axes of the ellipse from which the ellipse may be described by any one of the methods for drawing an ellipse. Art. 108, page 134.

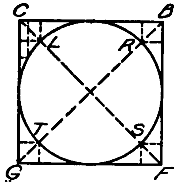


FIG. 50

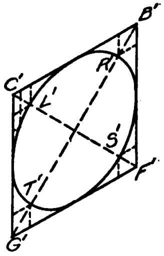


FIG. 51

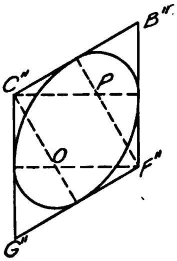


FIG. 52

Since circles and arcs of circles are the curves most frequently required, the following approximate method may be used. On the face $C''B''G''F''$, Fig. 52, which is identical with Fig. 51, lines have been drawn from each of the obtuse angles C'' and F'' to the middle points of the opposite sides. Their intersection, O and P, will determine the centers for describing the small arcs, while points C'' and F'' will be the centers for the large arcs. Such a curve, described by four circular arcs, will serve for all representations of circles, especially as it is never possible to make a direct measurement of the isometric drawing of a circle, or cylinder.

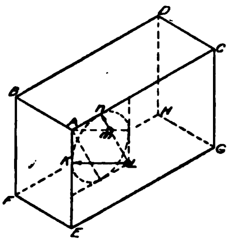


FIG. 53

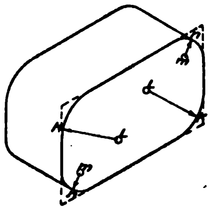


FIG. 54

Circular arcs for the rounded corners of an object should be obtained by constructing the isometric ellipse which will determine the two radii for all rounded corners of a given radius. Suppose it is required to round the corners of the block shown in Fig. 53 so as to appear as in Fig. 54. Construct the isometric ellipse within an isometric square, having its sides equal to twice the required radius. The two radii *lk* and *mn* will serve for all the corners by describing the arcs tangent to the edges.

Fig. 55 is an isometric drawing of a cube having a representation of a recess on the right hand face, a square projection on the left hand, and a cylinder on the upper face. The construction lines necessary to drawing the cylinder are shown by the dotted lines. The diameter of a circle, isometrically represented, must be obtained by determining the length of a side of the isometric square circumscribing it.

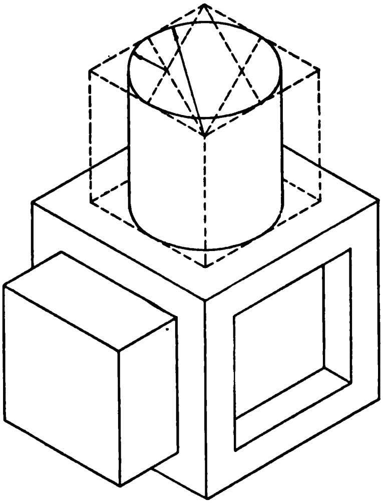


FIG. 55

37. Oblique and Cabinet Representations. — By these systems one face of the object is drawn as parallel to the observer, and faces perpendicular thereto are drawn at an angle as in Figs. 56 and 57, the only difference between the two being that in oblique representations the slant edges are drawn to the same scale as the front face, while in cabinet representations these are drawn to half scale. The angle of slant edges is usually made 45°, but any other angle may be used as shown in Fig. 58, which is an excellent illustration of a common application of cabinet projection to the representation of furniture for which this method is well adapted.

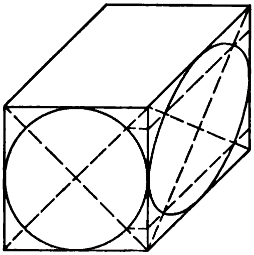


FIG. 56

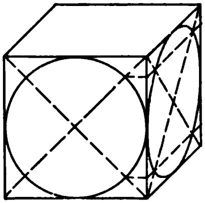


FIG. 57

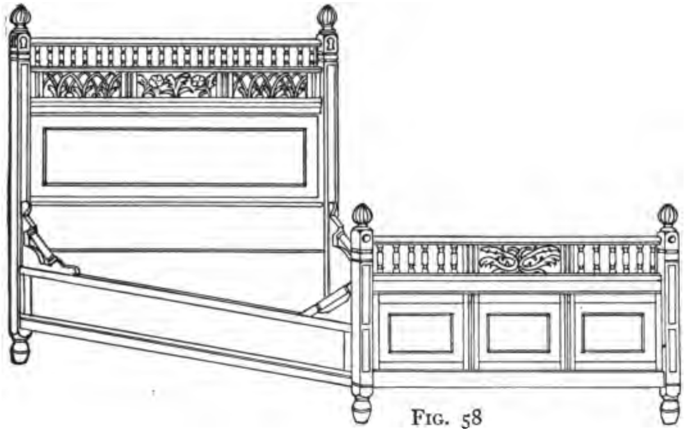
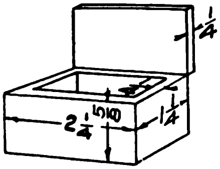
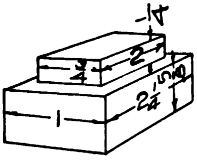


FIG. 58

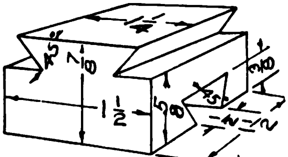
Problems in Isometric Graphics



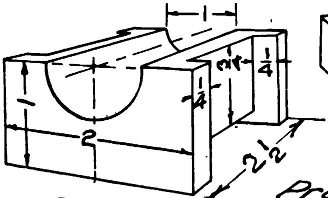
Problem 1



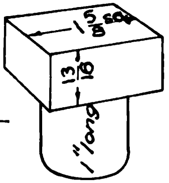
Problem 2



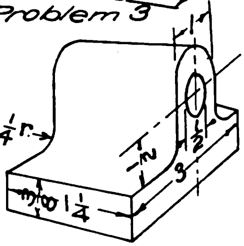
Problem 3



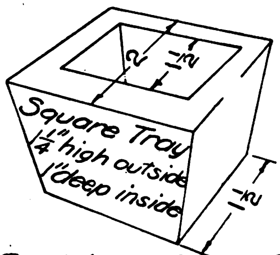
Problem 4



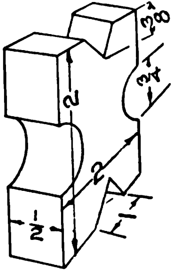
Problem 5



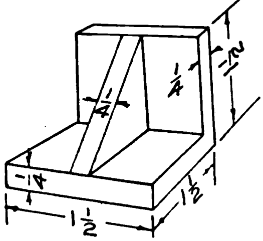
Problem 6



Problem 7



Problem 8



Problem 9

CHAPTER II

THE GRAMMATICAL CONSTRUCTION OF THE GRAPHIC LANGUAGE

38. The Limitations of Pictorial Graphics. — While pictorial illustrations lend themselves to an easy interpretation of ideas graphically expressed, the various systems are insufficient for a complete expression of other than the simplest objects. The limitations of these methods are as follows:

Perspective limitations are three in number:

FIRST. — The considerable difficulty involved in making correct perspective drawings to scale.

SECOND. — The inability to obtain dimensions directly from the drawing.

THIRD. — The confusion caused by attempting to represent other than the visible portions of an object.

39. Isometric Limitations. — Isometric, oblique, cabinet and other allied methods of projection have the following limitations:

FIRST. — The apparent distortion of an object by reason of its similarity to the perspective representation. This is especially true when applied to the representations of a building, or group of buildings.

SECOND. — The inability to obtain dimensions on other than isometric axes, and especially the inability to obtain the direct measurement of all cylindrical or other curved representations.

THIRD. — The confusion caused by representing other than the external features of an object.

40. The Front, Top, and Side View Method of Graphic Representation. — From the foregoing statement of limitations in the pictorial methods of graphic expression it is evident that a more satisfactory system must be devised for the practical representation of complex objects. It will be necessary, however, to abandon the attempt to express in one view the entire idea, and necessitates a greater mental effort in reading the drawing.

Consider the object represented by Fig. 59, which is the perspective drawing of a rectangular block with a square hole in its center and a wedge-shaped projection on the ends of its upper face. For such a simple object the perspective representation would suffice, especially when accompanied with the dimensions, but if it is necessary to obtain a drawing from which measurements can be made, or if the object is of a complex character, the perspective drawing is inadequate and the following method should be used.

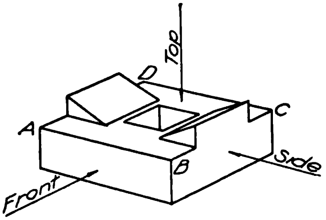


FIG. 59

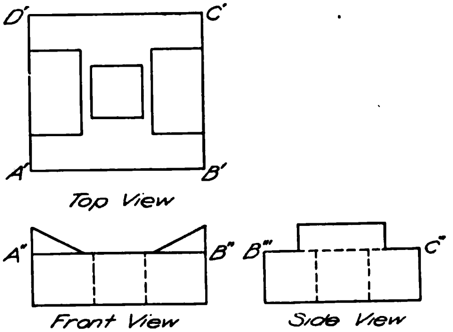


FIG. 60

Instead of one representation of the entire object, it is proposed to make three, and they are to be called views. One is from above and is known as the **top view**, another is from the front and known as a **front view**, while the third is from the right or left side and known as a **side view**.

Fig. 60 is a representation of the object by this method showing three views drawn as they really exist when viewed from points directly opposite each face, care having been taken to place the right side view directly to the right of the front view and the top view directly over the front view.

These representations being drawn to scale enables one to measure all the lines of the object. It is the method universally adopted in technical graphics such as engineering drawing.

It requires more imagination to read this type of drawing because an entire surface may be represented by a single line, or a line may be represented by a point. Thus in the front view, the entire upper surface, which is shown in the top view by $A'B'C'D'$, is represented by the line $A''B''$; and in the side view, the front edge of the upper surface AB is represented by the point B'''.

The invisible lines and surfaces are represented by dotted lines.

The relation of the three views must be strictly observed as their relative position is as important to graphic expression as that of the parts of speech in a sentence. The top view must be exactly over the front view, and the side view exactly to right or left of the front view, depending on the side shown.

41. Projection. — The method of projecting an object, as understood in Graphics, is well illustrated by the picture machine by means of which a picture is projected, on a screen.

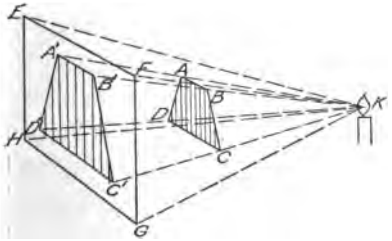


FIG. 61. PERSPECTIVE PROJECTION

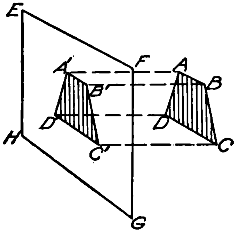


FIG. 62. ORTHOGRAPHIC PROJECTION

Fig. 61 illustrates the projection of a surface, $ABCD$, on a screen, $EFGH$, by means of rays of light from the source K, the projection being $A'B'C'D'$. If the source of light were moved to a greater distance, the shadow, or projection, would more nearly approach the size of the original, and if the projecting rays were parallel, the projection would be of the same size as the original, as shown by Fig. 62.

Fig. 63 is a perspective representation of a shaft bearing, which it is desired to express graphically by three views as in the preceding problem, Fig. 60. This example will be used to present the theory by which such representations are made.

Fig. 64 is a perspective view of the same object placed behind a vertical transparent plane $GLMN$, and below a horizontal plane $GLKH$. If the object be viewed with the eye at the point P', the perspective appearance on the vertical plane will be $E'D'C'A'B'$. This view is obtained by determining points, such as A', in which the ray of light from point A of the object pierces the transparent plane.

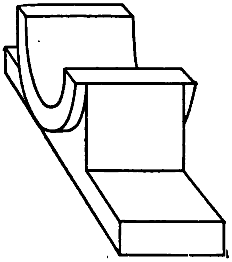


FIG. 63

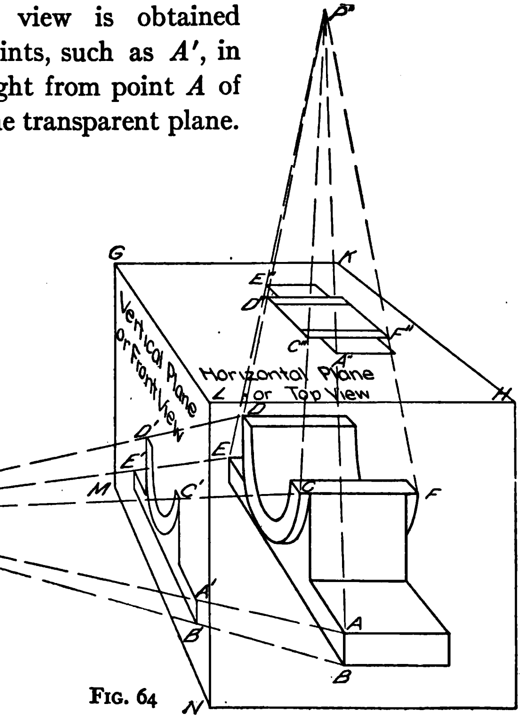


FIG. 64

The point A' as viewed from P' would exactly cover the point A of the object and is called the projection, or, in this case, the perspective, of the point on the transparent plane. Similarly, all the points of the object are projected onto this plane and the resultant figure is called the projection of the object.

In like manner, a projection, or perspective, is obtained on the horizontal plane, the position of the eye being at P'' directly above the object.

These views are smaller than the object itself and subject to the limitations due to perspective. Moreover, the two perspective views have no definite relation to each other as they are dependent on the distance of the eye from the picture plane as well as the distance of the object from these planes.

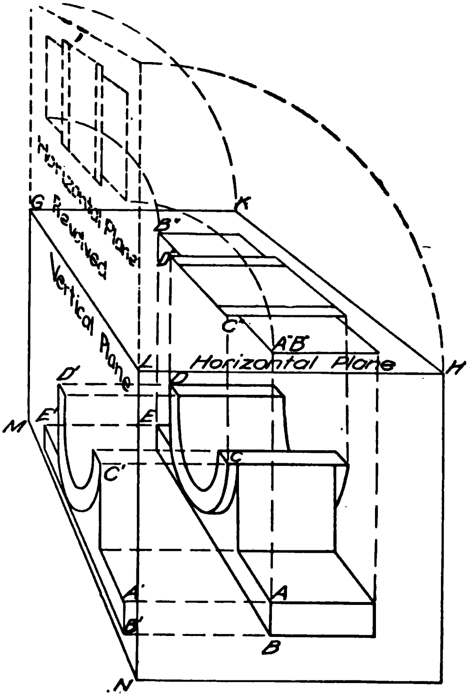


FIG. 65

42. Orthographic Projection. — In order to overcome the difficulties incurred by the perspective projection of Art. 41, imagine the eye placed at a very great distance from the object so that the rays of light from the object to the eye are practically parallel to each other and therefore perpendicular to the transparent plane. We may then obtain such a representation as shown in perspective by Fig. 65, in which the picture, or projection, is of the same size as the object, the distortion of perspective being avoided, and measurements may be taken directly from the drawing.

As it is not feasible to draw on planes at right angles to each other, and would be quite as impracticable to use such drawings, imagine the horizontal plane *GLKH* revolved about the hinge, or axis, *GL* until it is in the same plane as the vertical transparent plane. This operation and result is also illustrated by Fig. 65 which is a perspective view of the vertical plane, and of the horizontal plane before and after the revolution.

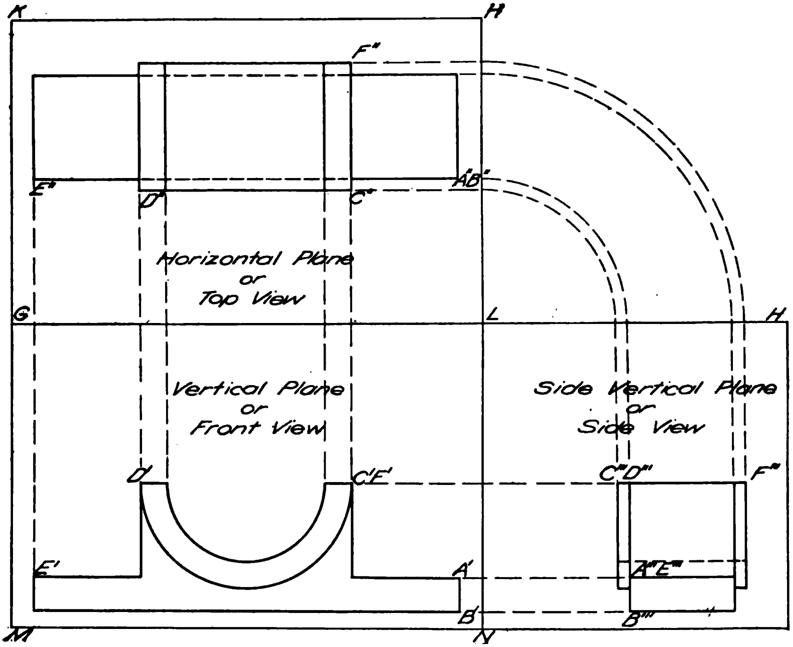


FIG. 66

Next, imagine these planes as viewed from a point directly opposite their common surface so that there is no foreshortening and the appearance will be that of Fig. 66, save that a side vertical transparent plane has also been added on which the side view of the object has been projected. We now have the orthographic projection of the object in three views.

As in written language the word orthographic signifies the correct writing and spelling of words, so in Graphics it signifies the correct writing or representation of surfaces and the true relation of the lines to each other. Orthographic projection is a system of projection in which the visual rays, or projecting lines are perpendicular to the planes of projection on which the representation appears.

43. Observation on the Relation of the Views. — By this method it will be observed that the projection of points in the top and front views must lie in a common perpendicular to *GL* the axis of the planes. For a like reason, the projection of corresponding points in the front and side views must lie in the same horizontal.

Note the following conditions which are dependent on the foregoing principles:

1. A surface will appear in its true size and shape on a projecting plane to which it is parallel.
2. A surface will appear as a line on a plane to which it is perpendicular.
3. A line will appear in its true length on a plane to which it is parallel.
4. A line will appear as a point on a plane to which it is perpendicular.
5. A top view gives no information as to breadth.
6. A front view gives no information as to depth.
7. A side view gives no information as to length.
8. At least two views are required to obtain the three dimensions of an object and the necessary understanding of the relation of the several surfaces and lines if fully expressed in graphic language.

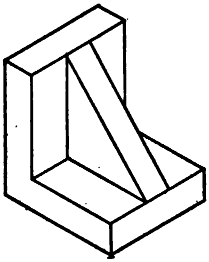


FIG. 67

44. Choice of Views. — The number of views necessary for a complete graphic description will depend on the character of the object to be described, but the arrangement of the views must be strictly in accord with the principles set forth in Art 42.

Since an increase in the number of views adds labor to the drawing as well as to the reading, they should be reduced to a minimum consistent with clear expression.

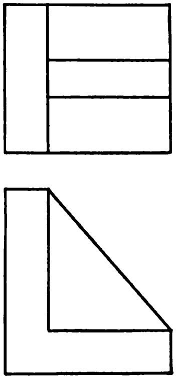


FIG. 68

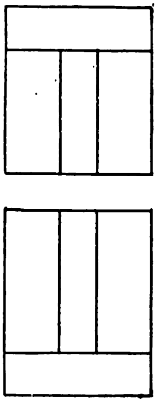


FIG. 69

In making a drawing, one should begin with that view which best expresses the most important features of the object and, if possible, use but one other view. As an unnecessary sentence, or paragraph, does not add to the force or clearness of expression, so an increase in the number of views may fail to add clearness to graphic expression.

Suppose it is required to make an orthographic projection of the bracket shown in Fig. 67. The view best suited to showing the character of the piece will be the lower, or front view of Fig. 68, which should be drawn first. From this view obtain the top view by projecting the corresponding points from the front view.

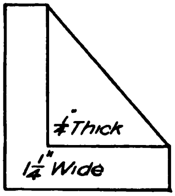


FIG. 70

It is frequently difficult for the novice to understand the importance of maintaining this relation between the views, believing that a correct drawing of the views should be all that is necessary even though the relation previously defined be not maintained, but this claim is as erroneous as would be that of transposing the parts of speech and words in a sentence and claiming the idea to be expressed inasmuch as the sentence contains all the necessary words. Graphic orthography must be as consistently observed as that of English.

Again, we must see that the idea is expressed in the most direct manner so as to convey the desired impression at first sight. To illustrate, suppose the bracket of Fig. 67 had been expressed as in Fig. 69. This is perfectly correct so far as the projection is concerned, but is difficult to understand at a glance, and fails to explain the form of the brace.

It is frequently possible to express an idea in one view, but it always implies added information in the nature of written notes. Fig. 70 is an example, and is a concise and proper method of expressing all the details of the bracket shown in Fig. 67. It implies symmetry in the position of the brace, and symmetry is always implied unless otherwise specified.

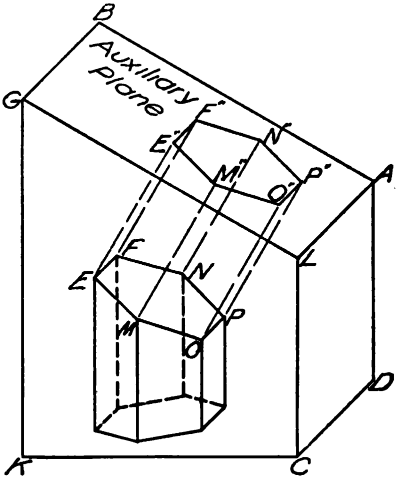


FIG. 71

45. Auxiliary Views. — One is not confined to the use of the three projecting planes used in the preceding cases as planes at any angle may be used if desirable. Fig. 71 illustrates a perspective view of a hexagonal prism having its upper base cut at an angle with the lower base, and it is required to project this upper base onto a projecting plane which is parallel to it, so that it may be seen in its true shape and area. (See Art. 42, Note

1.) The prism is illustrated as seen through three planes of projection, one of which, $GLAB$, is parallel to its upper base and perpendicular to the front vertical plane, $GLCK$. A side vertical plane, $LADC$, is also shown as perpendicular to the front plane. The front and side views of the prism are omitted in this perspective view, but the projection of the upper base on the auxiliary plane, $GLAB$ is shown. This has been obtained by projecting lines perpendicular to the auxiliary plane as EE'', MM'', etc.

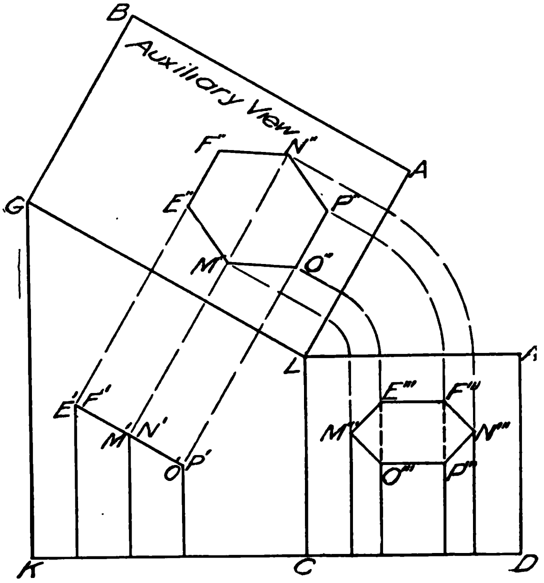


FIG. 72

Fig. 72 illustrates the three views as they would be drawn in orthographic projection after the several planes have been revolved into a common plane. Note that all lines which are perpendicular to the front plane of projection, such as EF, and OP, will be seen in their true length on the auxiliary plane, as well as on the side view.

Each edge of the prism, save four of the lower base, will be found parallel to one of the three projecting planes, thus making it possible to obtain their true length; and since the lower base is a regular hexagon the length of all the edges and the shape of all the surfaces may be obtained.

Fig. 73 illustrates the use of an auxiliary plane as a substitute for a top and side views when only the front and auxiliary views are given. Since the auxiliary view is used to define the character of the prism and the hole passing through it, it is unnecessary to include the projection of the base on this view.

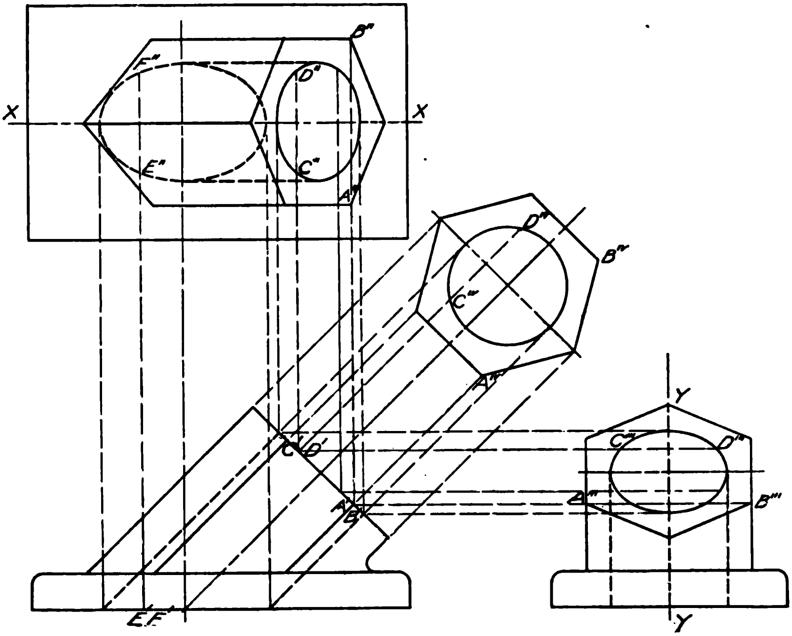


FIG. 73

to include the projection of the base on this view.

To obtain the top and side views, having given the front and auxiliary views, proceed as follows:

Draw the center lines of top and side views, *XX* and *YY*, and since all lines perpendicular to the front plane will be seen in their true length on the top, side, and auxiliary views (Art. 42, Note 3) the opposite corners of the hexagon *A* and *B* will appear on the front view as a point, $A'B'$, while on the auxiliary view the true distance between them, A^{IV} B^{IV}, will be seen, and this will be the same in the top view, $A''B''$, and in the side view, $A'''B'''$.

Similarly, points C and D on the upper end of the cylindrical opening may be determined on the other views. Note also that C^{IV} D^{IV} on the auxiliary view are the projections of points E' and F' in the lower end of the cylindrical opening.

All the ellipses which appear on the top and side view may be obtained by determining their major and minor axes and describing the curves by the trammel method. (See Art. 108, page 134.)

Problems on Projection

1. How many planes of projection may be used for the representation of an object?

2. Must the planes of projection be either vertical or horizontal?

3. What is the minimum number of views required for the graphic expression of an object?

4. What view of an object should be drawn first?

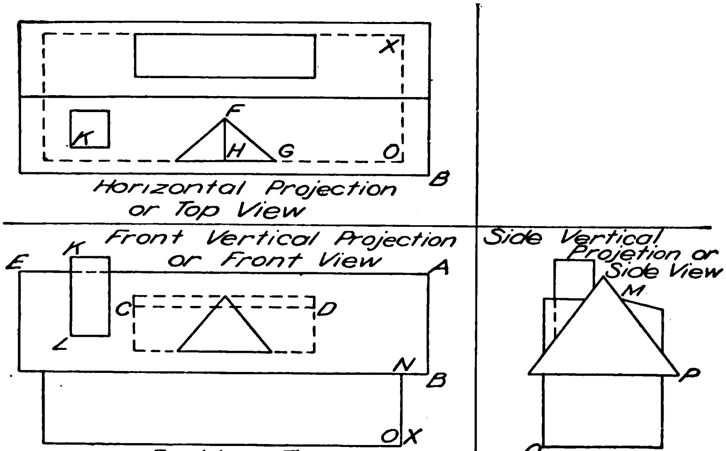
5. On what plane of projection would one look for the true shape of a surface?

6. Draw the outline of the walls and roof of a house similar to Fig. 37 page 38, making four representations, one each in perspective, isometric, oblique and orthographic projection.

7. Make a freehand tracing of the accompanying orthographic description of a house. Indicate by letters in each view the following lines, *AB, NO, CD, FG, FH, HG, DM, AE, KL, EP.*

When a line appears as a point, the letter for the point nearer the observer should be given first, as represented by the line *OX* in the front view.

Problems 8 to 28 inclusive. Draw a front, top and side view of each object as indicated in the perspective representation. Every line of the object must appear in each view. The visible lines will be drawn full, and the invisible lines dotted.


X
K
F
H
G
O
B
Horizontal Projection or Top View
Front Vertical Projection or Front View
E
K
A
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D
L
N
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X
Side Vertical Projetion or Side View
M
P
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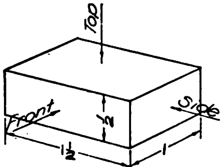
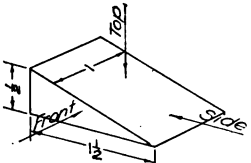
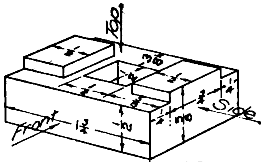
Problem 7



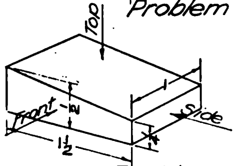
Problem 8



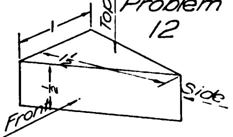
Problem 12



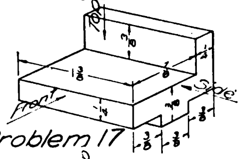
Problem 16



Problem 9



Problem 13



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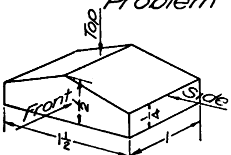
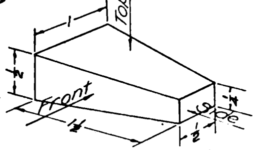


Problem 10



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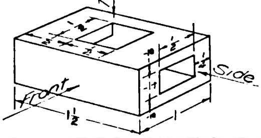

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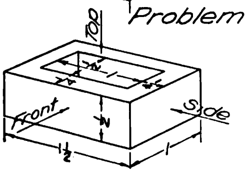

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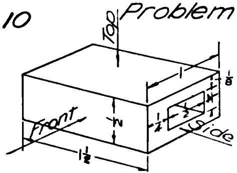
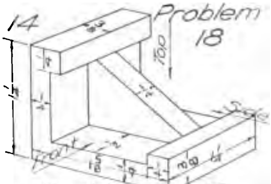
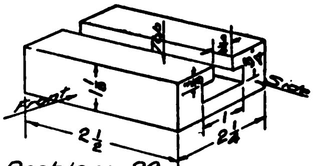


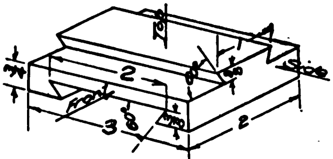
Problem 15



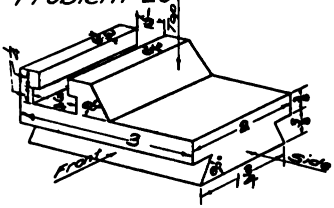
Problem 19



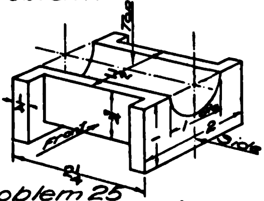
Problem 20



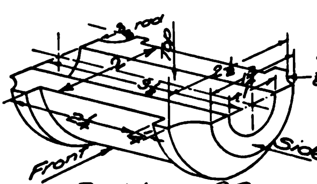
Problem 24



Problem 21



Problem 25



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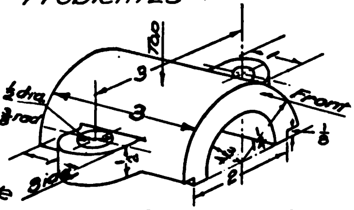
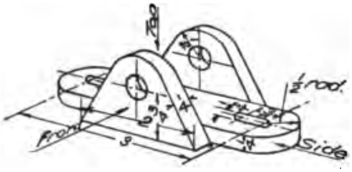
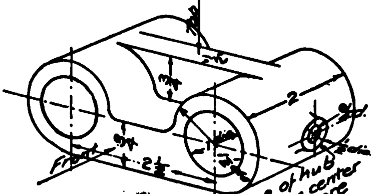


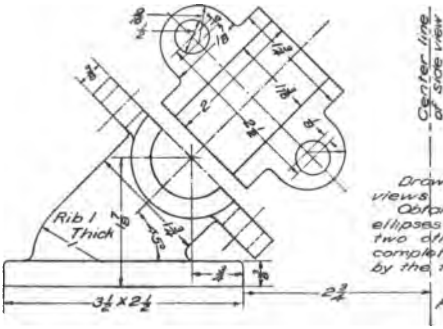
Problem 26



Problem 23



Problem 27



Draw top and side views. Obtain axes of ellipses and at least two other points completing the curves by the trammel method.

Problem 28.

CHAPTER III

IDIOMATIC GRAPHICS

46. Sectional Views. — When an object is represented by external views it frequently occurs that there are lines and surfaces within the object which are not made sufficiently clear by means of dotted lines, which is the notation for invisible lines. In such cases it becomes necessary to represent the object as though a part of it had been removed so as to give the observer an unobstructed view of the parts previously concealed. Such views are known as sections and they are essential to a clear graphic expression of the more complicated objects. Also they are most useful in testing one's understanding of a drawing for if one is able to make various sections of an object a thorough knowledge of its character is assured.

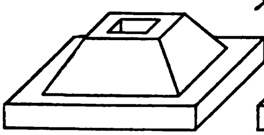


FIG. 74

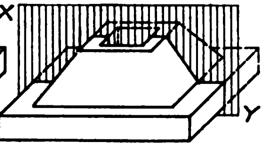


FIG. 75

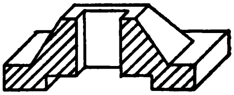


FIG. 76

Fig. 74 illustrates an object by oblique projection, the interior of which it is desired to explain. If an imaginary plane, XY, be passed through the center of it, as in Fig. 75, and the front portion be removed, the appearance would be as in Fig. 76, which is a sectional view and clearly shows the inner portion of the object.

Fig. 77 is an orthographic front and top view of the same object in which the interior is shown by means of dotted lines.

Fig. 78 illustrates the same by a sectional view made by a vertical plane *XY* passing through the center. In the latter view it will be observed that the interior is now shown by full lines but that there are two classes of lines: first, those made by the cutting plane, such as *AB*, *EF*, *CB*, and *CD*; second, those lying beyond the cutting plane, as *AE*, *BF*, *DK*. Were it not for these last named lines, the figure would appear disconnected as though consisting of two different pieces.

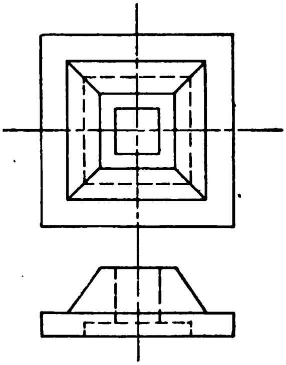


FIG. 77

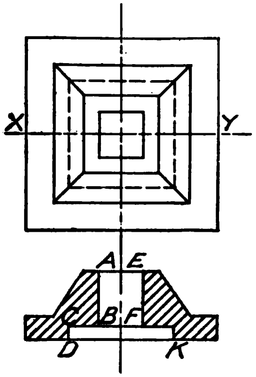


FIG. 78

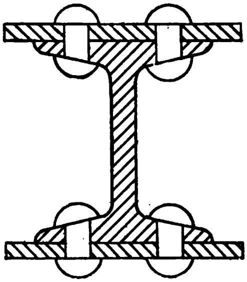


FIG. 79

47. The Sectional View Distinguishes Between Different Pieces. — When two or more pieces are in contact, and represented in section, a change in the direction of the section lining will clearly indicate the separate pieces. Fig. 79 illustrates an I beam with plates rivetted to the top and bottom of it. These plates are clearly distinguished from the beam by changing the direction of the sectional lining. The rivets are shown in full but they might have been sectioned also by adopting a direction of lining different from that already used; it is customary however not to section cylindrical pieces such as bolts, pins and rivets.

48. Dotted and Sketched Sections. — Figs. 80, 81, and 82 represent different methods of illustrating sectional views, the subject being two objects of circular form, the upper of which is inserted in the lower, or base.

Fig. 80 is an outside, or full view, with dotted lines to represent the section. It fails to make clear the separate pieces and the method of uniting them. Note the absence of lines from *M* to *N* and *O* to *P* which are shown in Figs. 81 and 82, but which might cause confusion in the outside view.

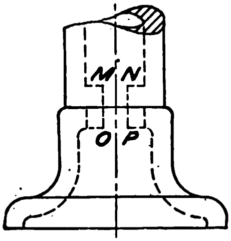


FIG. 80

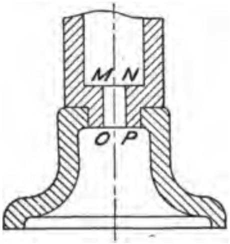


FIG. 81

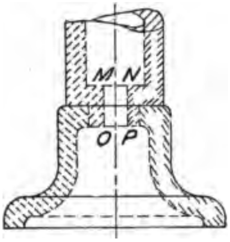


FIG. 82

Fig. 81 is a correct sectional view with the relation between the parts clearly designated.

Fig. 82 illustrates two methods of indicating the separate parts in an outside view of the object. That to the left of the center line is a dotted section and need not necessarily be reproduced on the right of the center. That to the right of the center illustrates the method of drawing or sketching the section lines which is used by draftsmen on penciled drawings and sketches.

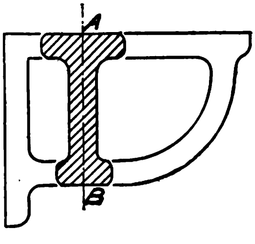


FIG. 83

49. The Sectional View Need not be Drawn as a Separate View. — Fig. 83 is a drawing of a bracket with a section made by a cutting plane on *AB* revolved so as to appear on the main view. This gives complete information of the object and is the equivalent of two views.

50. The Vocabulary of Section Lines. — In order to distinguish between the various materials which may appear in a section, it is necessary to make a variation in the cross section lines as indicated in Fig. 84. There is no universal agreement as to the notation, save in the first section of equidistant full lines which usually represents cast iron, but may be used for any material by writing the name of the material on the section. The character of the material indicated by the other sections is varied somewhat in different industries and by different engineers, but the notation is suggestive of types commonly used.

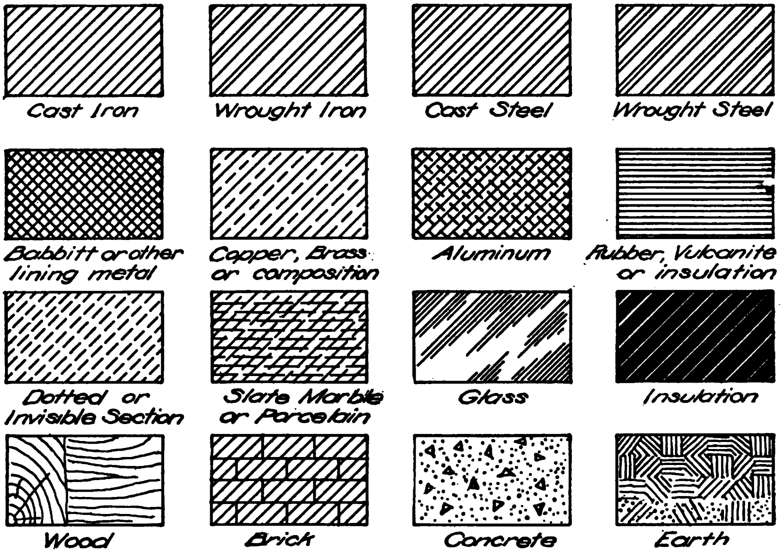

Cast Iron
Wrought Iron
Cast Steel
Wrought Steel
Babbitt or other lining metal
Copper, Brass or composition
Aluminum
Rubber, Vulcanite or insulation
Dotted or Invisible Section
Slate Marble or Porcelain
Glass
Insulation
Wood
Brick
Concrete
Earth

FIG. 84. — VOCABULARY OF SECTION LINES

51. Idiomatic Graphics. — Since the object of graphic language is to give facility in the interchange of thought, it must fulfill the requirements imposed on all languages as regards clearness of expression and brevity. Both of these conditions lead to the use of certain phrasing which we term idioms, and the graphic language is full of idiomatic expressions.

In the making of sectional views one soon discovers that a strict observance of grammatical expression (orthographic projection) frequently leads to confusion, and this must be avoided if clearness and brevity are essential. Figs. 85 to 88 illustrate this principle. Fig. 85 is a correct projection of a disc having a hub on its upper surface with a hole passing through it. There are four ribs connecting the hub with the disc, all being a part of the same piece. Since a sectional view with a single note of explanation will suffice to express the object, and avoid the making of a top view, the representation of Fig. 86 may be used to replace the two views of Fig. 85. This is a sectional view on a plane AB, passing through the center; but it will be observed that the ribs are not included in the sectioning, as they should have been for a strict observance of the law.

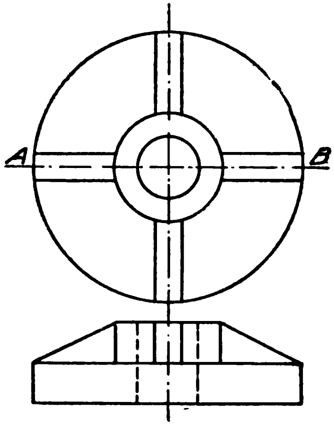


FIG. 85

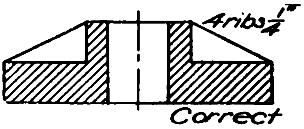


FIG. 86

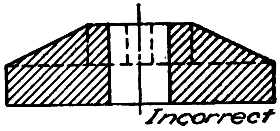


FIG. 87

Fig. 87 illustrates the effect produced by adhering strictly to the law, which would necessitate sectioning everything that appears in the plane of the section passing through the center of the disc, but it is misleading because there is not a clear distinction between the hub, ribs, and disc, and, also, the first impression is that of a solid conical shaped object.

52. The Graphic Representations of Symmetrical Objects Should Suggest Symmetry. — In general one should section only that portion of a cylindrical object which is continuous, treating other details as accidentals. Fig. 88 represents a face and sectional view of a wheel with four arms, the section being made on the plane *AB* passing through the center, but the arms are represented as though lying directly back of the section. Had the arms been shown in section, the representation would have been identical with the section in Fig. 89, which represents a wheel with a solid web.

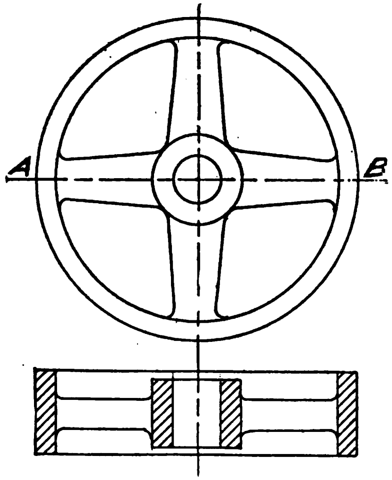


FIG. 88

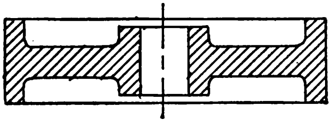


FIG. 89

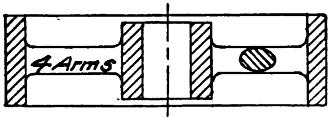


FIG. 90

While it may be said that the face view would correct any erroneous impressions that might be made by sectioning through the arms, it is necessary to use the same caution to avoid false impressions in graphic language that one would use in any written language. Moreover, the sectional view of Fig. 88 may be made to supply all the necessary information without the use of a second view by affixing a note stating the number of arms, and designating their shape by a revolved cross section as in Fig. 90.

The importance of suggesting symmetry is well illustrated by Figs. 91 to 94. Fig. 91 is a face, or front, view of a flanged wheel having 5 arms, or webs. The correct sectional view being that of Fig. 92. It may be represented also as in Fig. 93 in which the arm is suggested by a variation in the width of the section lines. Fig. 94 is a view made by a true representation of the section that would be produced by a plane passing through the center of the wheel, but it is incorrect inasmuch as it fails to suggest the symmetry which characterizes the piece.

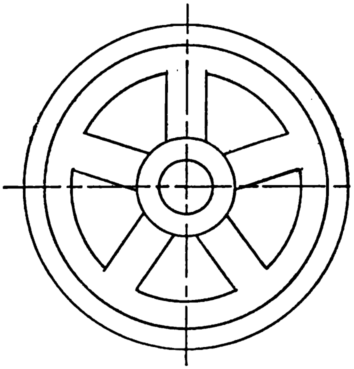


FIG. 91

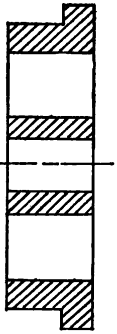


FIG. 92

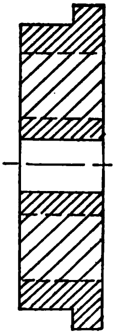


FIG. 93

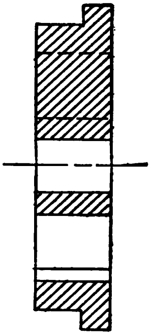


FIG. 94

The principle is again illustrated by Fig. 95, which represents a cylindrical piece, having a slot, or keyway, cut on the inner portion so that the coupling could be prevented from revolving on the shaft by means of a key. If the plane of the section passes through the slot or keyway, the section will appear un-

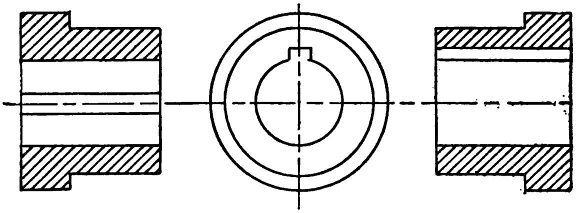


FIG. 95

symmetrical as shown at the right, but if the view be treated idiomatically, as shown at the left, even though the slot is not projected according to graphic law, it will not mislead the reader.

Another excellent example of idiomatic sectioning is that of Fig. 96, which represents a hollow cylindrical object with three ribs connecting the flange and the cylinder. The flange has three hubs with holes in each. Within, and at the bottom of the cylinder, is a rib enlarged at the center for a hole.

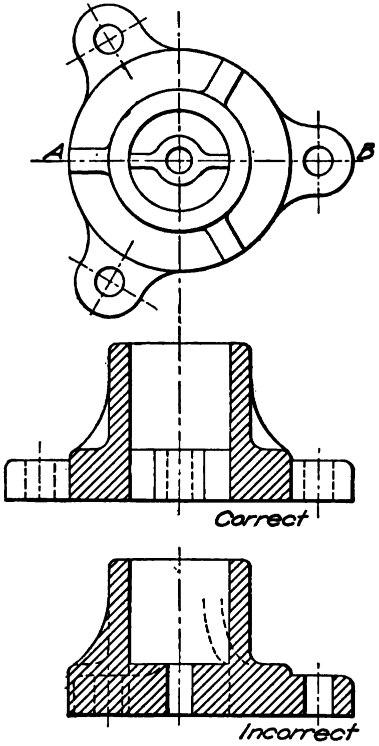


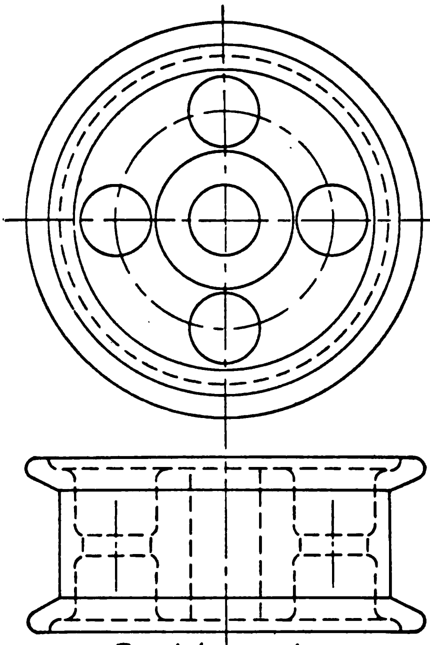
Fig. 96

The correct sectional view expresses the idea of symmetry which really exists, although not with respect to all axes. It emphasizes the important feature which is that of a hollow cylinder with a flange, the other features of hubs and ribs being what may be termed accidentals.

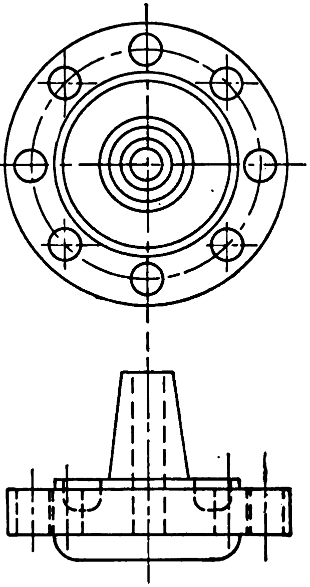
The incorrect view which is orthographically correct is a true sectional view on the plane AB, but it conveys no idea of symmetry, confuses the flange with the ribs and hub, and is in general misleading.

Problems on Idiomatic Graphics

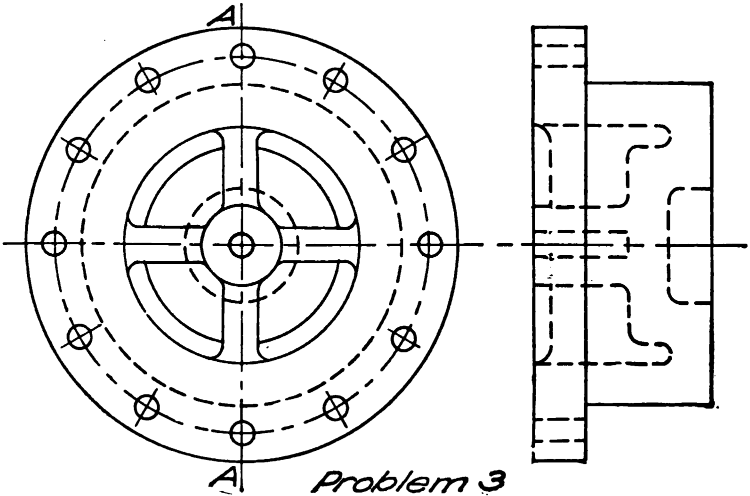
It is required to represent each vertical view as sectioned by a plane passing through the center. This may be done by tracing the illustration from the book, but as it would appear when sectioned, or by making a drawing of double the size of the illustration and representing it in section.



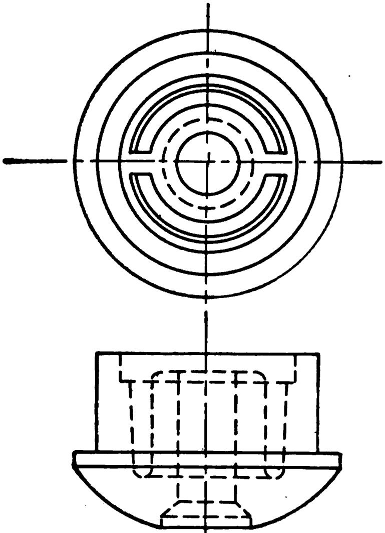
Problem 1



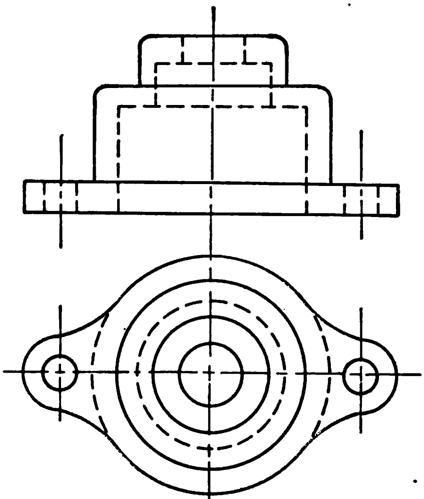
Problem 2



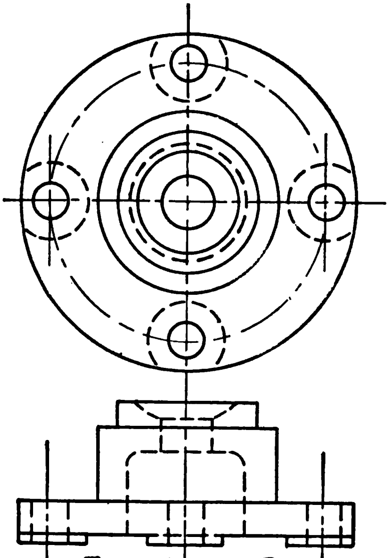
Problem 3



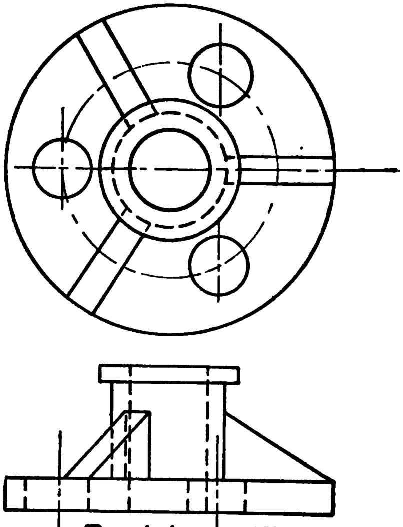
Problem 4



Problem 5



Problem 6



Problem 7

CHAPTER IV

TECHNICAL GRAPHICS

53. The Historical Development of Engineering Graphics. — Until the early part of the nineteenth century the demand for graphic expression came chiefly through architecture, and engineering work of a simple character. The mechanical devices which were introduced through the arts of war and engineering were largely described in a pictorial manner, whenever more than a written description was necessary. During this period no technical difficulties were encountered in the rendering, or reading of drawings; not until the development of steam gave rise to the production of power, independent of wind and water, did Graphics begin to grow and the expression of thought through lines assume the dignity of a language. But with the development of mechanisms the inaccuracies due to the crude methods of pictorial representation led to confusion and increased expense in construction, thus necessitating the development of a graphic language.

In the early part of the nineteenth century the demand for increased facilities in transportation and manufacture stimulated inventive genius and introduced the age of engineering which has characterized the last century. This great development of mechanic arts, which was conspicuously active between 1830 and 1860, encouraged the study of mechanism which had been anticipated already by three noted French scientists; Monge, who is considered to be the father of descriptive geometry; Carnot, whose name is associated with the development of the theory of heat, and Ampere of electrical fame. Finally, within the period named, came the great contributors to the literature of the science of mechanism, Willis, Rankine, and Reuleaux, their publications covering the period from 1841 to 1874.

In addition to the study of mechanism, there was a phenomenal development in invention, and the dates of a few of the most important ones will enable one to appreciate the great demand which was being made for graphic language.

The evolution of the steam engine, which had been in progress during the 18th century, had reached a practical stage at the beginning of the 19th century through the inventive genius of James Watt, and in 1807 the steamboat Clermont made its first memorable voyage from New York to Albany. This was followed in 1829 by George Stephenson's locomotive, the " Rocket," which assured the future success of railroad engineering.

From 1830 to 1860, the steam engine went through its most important stages of development in theory and practice, thus solving the problem of power for manufacturing and transportation.

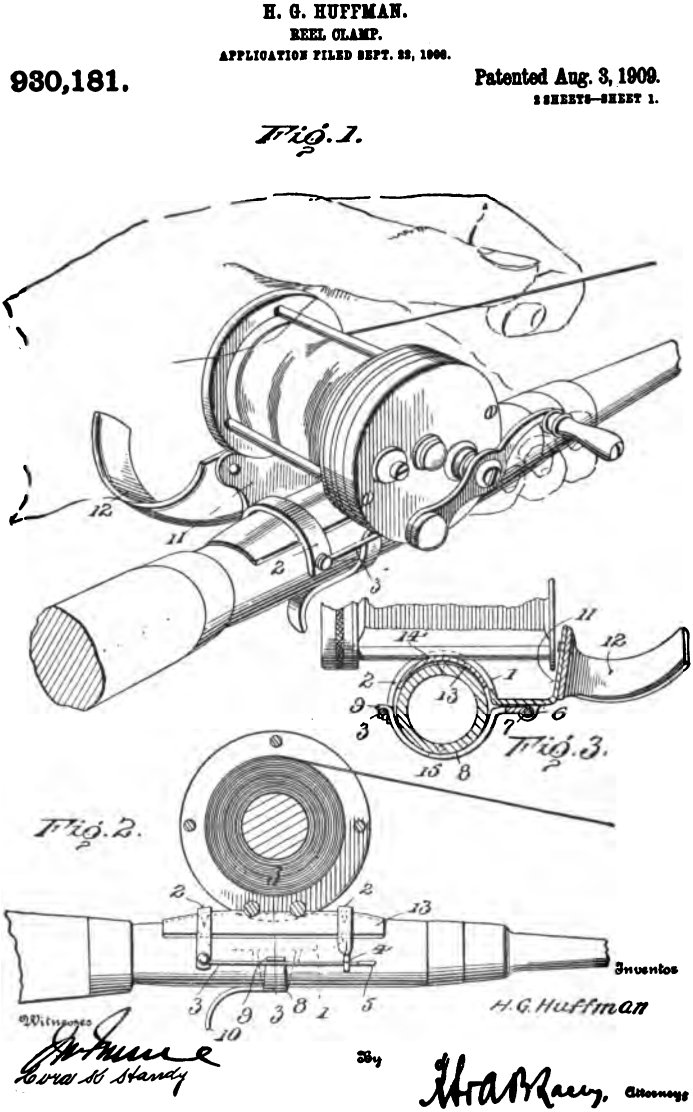
In the field of manufacturing, no more interesting development has taken place than that of the sewing machine, the first machine having been built by Elias Howe in 1843. This was followed by the inventions of Wilson in 1849, Singer in 1851, and Gibbs in 1856. Goodyear's method of vulcanizing rubber dates from 1839, McCormick's reaping machine in 1834, the power loom in 1846, and the rotary printing press in 1847.

During the above named period, a very great number of models were constructed in wood, or metal, to enable the relative motion of the several parts of mechanical devices to be seen and studied. This was an acknowledgment of ignorance in the use of graphic language, and a failure to appreciate the adequacy of the language to fully express complex ideas. The history of granting patents by the United States Government is a striking illustration of this phase of our struggle to graphically express technical ideas.

The Patent Office was established to protect the inventor from infringement on his rights, and thus to encourage invention. But adequate protection can be obtained only by a clear expression of the ideas embodied in the invention. The following methods are available: The English language, Graphics, and Models. As English is inadequate for the complete presentation of mechanical ideas, some form of graphic expression has been employed from the first to supplement the written language; but in all intricate devices the chief reliance was placed on a model. The Patent Office specified certain limitations as to its size, — the maximum being one cubic foot, — and encouraged the making of as small a model as possible. Two difficulties were soon encountered, the first being the storage capacity of the office buildings, and second, the complex character of the models.

At the beginning of the 20th century nearly 160,000 models had been stored for reference in the Patent Office at Washington, requiring about two acres of shelving and representing labor worth millions of dollars. This collection of mechanisms constituted a portion of the reference library of the Patent Office and was believed necessary because of the supposed inadequacy of English and the Graphic language, but today the department has found it necessary to suspend the reception of models and confines the inventor to the use of English and Graphics. Fig. 97, page 80, is a copy of a Patent Office drawing fulfilling all of the prescribed regulations as to representation.

In order to obtain a fuller appreciation of the precision necessary in expressing thought by this medium, consider the demands made by a single industrial establishment which is directing its employees solely by graphic language in the form of drawings, of which more than 25,000 are required annually. To inform properly the various artisans it is necessary to describe accurately every bolt, pin, shaft, and casting employed in the con-



H. G. HUFFMAN.
REEL CLAMP.
APPLICATION FILED SEPT. 22, 1908.

930,181.

Patented Aug. 3, 1909.
2 SHEETS—SHEET 1.

FIG. 97. A PATENT OFFICE DRAWING

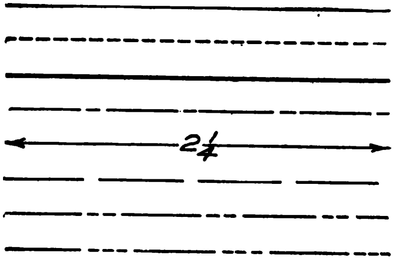
struction of the machines which may be manufactured, besides illustrating various devices for the manufacture of these pieces. These descriptions correspond to business letters, and the writing of them requires a force of men who are more than scribes, in that they must fully appreciate the requirements of the artisans whom they are addressing, as well as the technicalities of Graphics. Their business is to express the ideas in the most concise manner with absolute accuracy of detail, using the greatest care to avoid ambiguity.

The good draftsman must be able to make his idea clear, not only to the engineer and expert, but to the comparatively uneducated workmen as well; and above all, he must guard against being misunderstood. To do this he must receive a training such as would be given to a student of English, for although he may be able to outline perfectly the most complicated device, draw various sections for illustrating the inner parts, and supply the necessary dimensions, he may fail to interpret the idea concisely and clearly as much of modern drafting is idiomatic and apparently in direct opposition to the laws of projection, or grammatical construction. He must never forget the impression that is likely to be received by the person who may glance hastily at the sketch, or drawing, for if the wrong train of thought is suggested, the mind will cling most tenaciously to that course.

A great change has taken place in the practice of draftsmen during the past seventy-five years as regards the character of the drawings. Formerly the draftsman was regarded as more of an artist than engineer, and the best drawings were executed with a refinement of artistic detail that is entirely disregarded today. Very fine lines were commonly used, and not infrequently rounded surfaces were distinguished from planes by means of the line shading as in Fig. 99, page 83. Water colors were also used to indicate the character of the material and to define sectioned surfaces.

Today a rather heavy line is used for most work, shaded surfaces and shade lines, Fig. 98, little used, and all colored or wash drawings discontinued. The drawing has ceased to be regarded as a picture, or work of art, but as a written description of work to be constructed. It has become very idiomatic and its vocabulary is increasing rapidly.

54. The Vocabulary of Lines, Shade Lines, and Line Shading. — Since the various classes of lines constitute the alphabet by means of which the vocabulary of graphic language is written, it is necessary to understand the generally accepted signification of the most used types. These are illustrated as follows:



Line for visible surfaces.

Line for invisible surfaces.

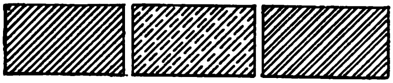
Shade line.

Center line.

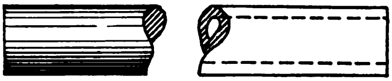
Dimension line.

Witness line.

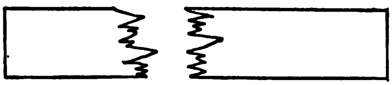
Miscellaneous lines used for various purposes.



Cross hatching. This is used to indicate sectional surfaces as explained in Chapter III, Page 67.



Broken material. Metal. The section of the surface is made to suggest the shape of the material.



Broken material. Wood. A jagged line is used to indicate all kinds of wood.

The shade line as previously indicated is little used today, but is very useful for indicating the relation of surfaces in a complicated drawing. Such lines are an aid to reading only when their significance is understood. Fig. 98 illustrates the theory of their use which is based on the supposition that the light is coming from the upper left hand corner of the object, and the surface in shadow is represented by a heavy line. The shade line is used also for the division line between light and dark surfaces. Do not shade cylindrical surfaces.

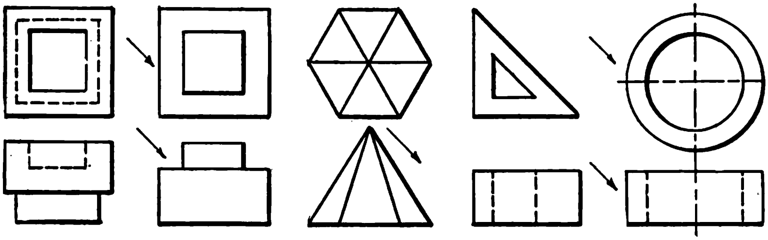


FIG. 98. SHADE LINES

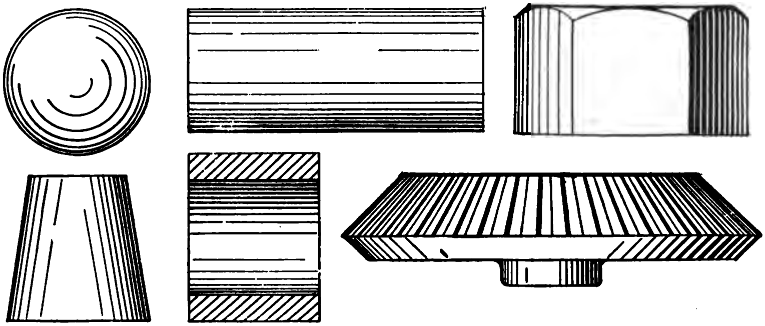


FIG. 99. LINE SHADING

The rule which the writer of Graphics should adopt is never to use the shade lines unless it will serve to give a more ready interpretation of the idea.

Line shading is but little used in practical work, save in Patent Office drawings where it serves the purpose of picturing the character of surfaces when the number of views is limited. Fig. 99 illustrates several types of shading curved surfaces.

55. The Conventional Representation of Bolts and Screws. — Bolts and screws serve as the stitches of machinery, being the most common means of uniting the several parts of a machine. They are used to so great an extent that it is necessary to simplify their representation by adopting a special vocabulary.

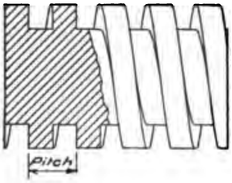


FIG. 100

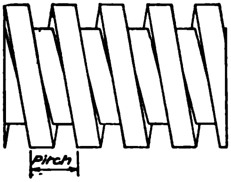


FIG. 101

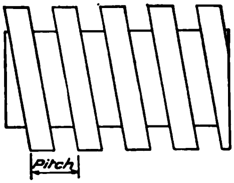


FIG. 102

56. Screw Threads. — Fig. 100 is a representation of a square thread, or screw, in both a sectional and full view, showing the correct form of the curve which is called a helix. (See Art. 122.)

Because of the labor involved in making such a representation, it is necessary to conventionalize it as in Fig. 101 by the substitution of right lines for the helical curves. It may be further simplified, as in Fig. 102, by omitting the lines of the inner helix, and this latter form is more common.

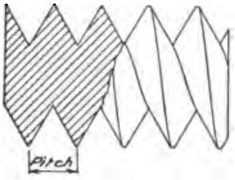


FIG. 103

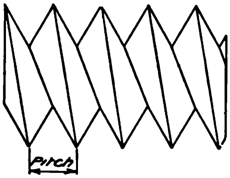


FIG. 104

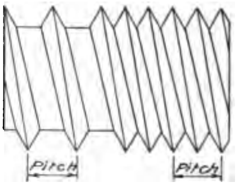


FIG. 105

The *V* thread screw is similarly represented in Fig. 103 and conventionalized in Fig. 104, although the latter form is further simplified for engineering practice as in Figs. 106 and 107.

57. Single and Double Threads. — It will be observed that in both the types previously illustrated, the distance between the consecutive threads, or what is known as the "pitch," is equal to the distance which the screw would advance in receiving one entire turn. These are called single threads. Now, suppose the root of the thread to be partly filled, as shown at the left hand of Fig. 105. The pitch would not be altered, and it would be possible to wind about this form an intermediate thread, as shown at the right of Fig. 105. There would then be two threads of the same pitch, but independent of each other. This is called a double thread.

In the case of double threads it will be observed that the points of the threads are diametrically opposite while in the single thread, Fig. 104, the outer point is opposite the inner point, or root, of the thread. This principle is observed in making the conventional thread *A* of Fig. 106.

58. Right and Left Hand Threads. — The threads previously shown are right hand, which signifies that they would advance from the operator if he were stationed at either end and revolved the thread clockwise. The left hand thread would be shown with the conventionalized helix drawn downward to the left.

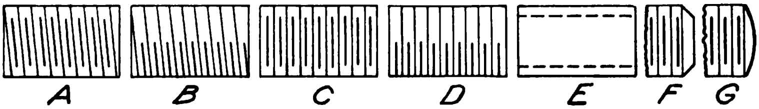


Fig. 106. Conventional *V* Threads

59. The Vocabulary of Screw Threads. — Fig. 106 illustrates the most used symbols for the representation of screw threads. Of these *A* is the one most used and is derived from Fig. 103 by omitting the *V*'s and making the thread lines parallel. *B* suggests a more simple method of drawing the root lines of the thread. *C* and *D* substitute perpendiculars for the slant lines of the conventionalized helix. *E* is the most simple type and is little used. The ends of screws are finished as at *F* or *G*.

The nut, or tapped hole into which a thread is designed to be screwed is represented in many different ways as shown in Fig.

107. *A*, *B*, and *C*, being in section would make the thread appear left-handed, save in the case of *B* which is not indicated by a slant line. *D* and *E* are for the representation of invisible threads. *F* is a tapped hole which does not pass through the piece. *G*, *H*, and *K* are similar to *F* but dotted.

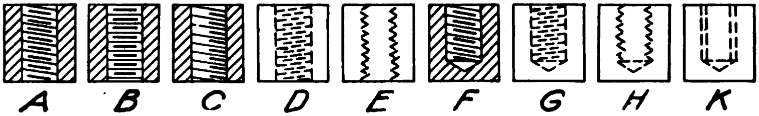


FIG. 107. CONVENTIONAL NUTS AND TAPPED HOLES

60. The Vocabulary of Bolts. — Bolt heads and nuts are either hexagonal or square. The proportions differ for varying uses but the Government standard for the hexagonal type is shown by Figs. 108 to 113. Assuming the diameter of a bolt as the unit of measurement, the distance across flats is made half as much more plus $\frac{1}{8}''$. The distance across corners is obtained by constructing a part of the hexagon as shown by the dotted lines of Figs. 108 and 109.

Figs. 108 to 110 are of the rounded type and Figs. 111 to 113 are chamfered. Figs. 108 and 111 show the head across flats, or the short diameter of the hexagon. Figs. 109 and 112 are across corners and Figs. 110 and 113 illustrate nuts.

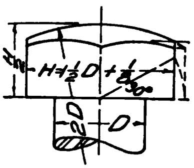


FIG. 108

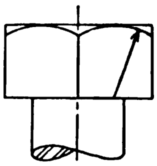


FIG. 111

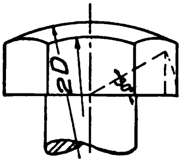


FIG. 109

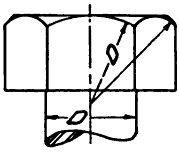


FIG. 112

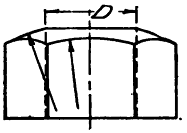


FIG. 110

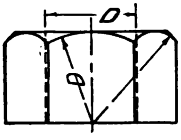


FIG. 113

For sketching purposes, the proportions may be simplified by making the distance across flats $1\frac{1}{2}$ diameters of the bolt, and the distance across corners 2 diameters.

Fig. 114 illustrates several types of screw heads which are in common use. Their names and general character are important, but their proportions need not be considered here.

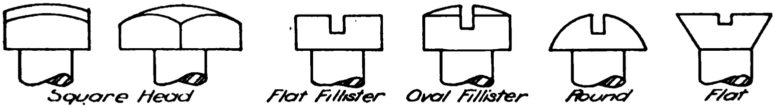


FIG. 114. SCREW HEADS

61. To Read a Technical Drawing with understanding requires a full knowledge of the significance of every line in all views and their relation to other lines and surfaces. This requires a simultaneous reading of the several views of the object, as any attempt to read but one view at a time will lead to erroneous conclusions which frequently are difficult to eradicate.

In reading from two or more views at one time, it is necessary to project from one view to another very rapidly, and this may be done frequently at a glance without the aid of instruments, but the work will be facilitated, and the possibility of error reduced, by the use of a pair of dividers, or even a card on which distances from a center or base line may be indicated. This operation is suggested in the Fig. 115 which is a front and top view of a piece of machinery known as a connecting rod end. It consists of nine pieces, five of which are illustrated in isometric by Fig. 117, and the other four are bolts of two different sizes. These five are also lettered to correspond with their representation in Figs. 115, 116, 117 and 118.

The isometric representations have been presented to facilitate the reading and visualization of the several pieces of the connecting rod, but in practice there would be no such aid and it would be necessary to read directly from the orthographic projection, as in Fig. 115.

Assuming that the student knows nothing of this special mechanism, and has no pictorial representation of the parts, he should proceed in a manner suggested by the following: —

From the front view of Fig. 155 it would appear that the

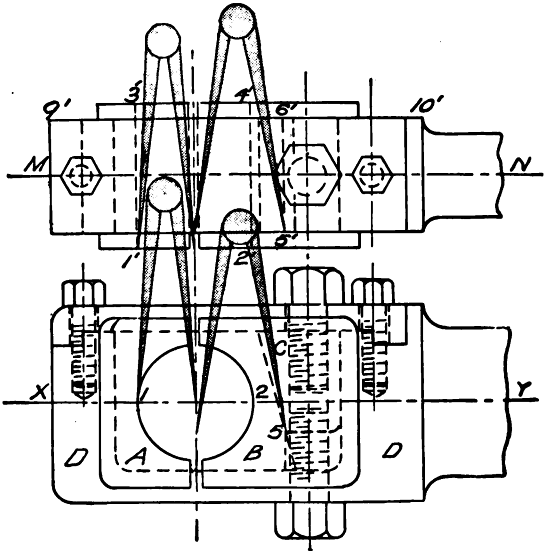


FIG. 115. CONNECTING ROD END

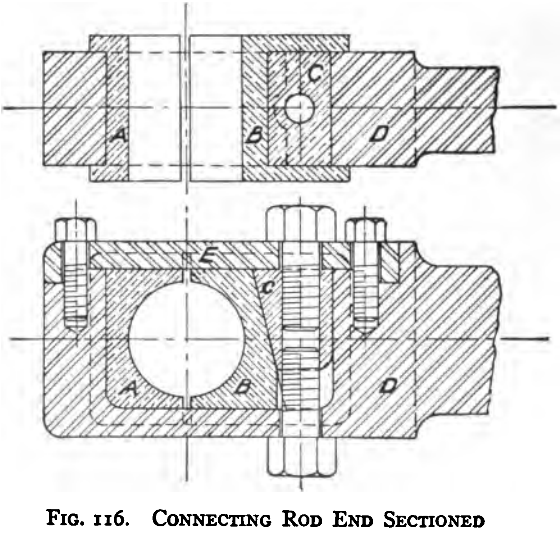


FIG. 116. CONNECTING ROD END SECTIONED

parts *A* and *B* have semicircular surfaces extending from front to back, but to assure oneself of the truth of the latter statement it is necessary to project an element of the cylinder onto the top view. To do so, place one point of the dividers at the center of the circle and the other at point 1, then project by moving the first point of the dividers up the center line to the top view. It will then be seen that the top view of the point is at 1′ and that 1′3′ is the top view of the element of the cylinder shown in the front view by point 1, and which extends from the front to the rear face. Had it been otherwise, the line would not have been parallel to the center line. Again, the line 5′6′ of the top view has no special significance until we project it to the front view and find it to be the bottom edge of the wedge *C* at point 5, the two positions of the dividers being shown. Also, we observe from the top view that the wedge extends from the face 7′8′ to the face 9′10′, or between the flanges of *A* and *B*.

Similarly check all the lines of the two views to account for all the lines and surfaces of the several parts.

There is no better way of testing one's understanding of such a drawing than by making a sectional view, or views. Fig. 116 represents two sections of this mechanism, the upper view being a section on a horizontal plane, *XY*, passing through the center, and the lower view a section on a vertical plane, *MN*, passing through the center. Observe that the bolts, although lying in the plane of the section, are not sectioned. Such sectional studies are best made for reading purposes by tracing directly from the respective views rather than by redrawing.

Figs. 115, 116, 117, and 118 are drawn to the same scale to assist the student in studying the several parts by using the dividers to compare the measurements in the different views.

62. Assembly Views and Details. — Fig. 115 is known as an assembly view, the several parts being shown in their proper relations when in working position.

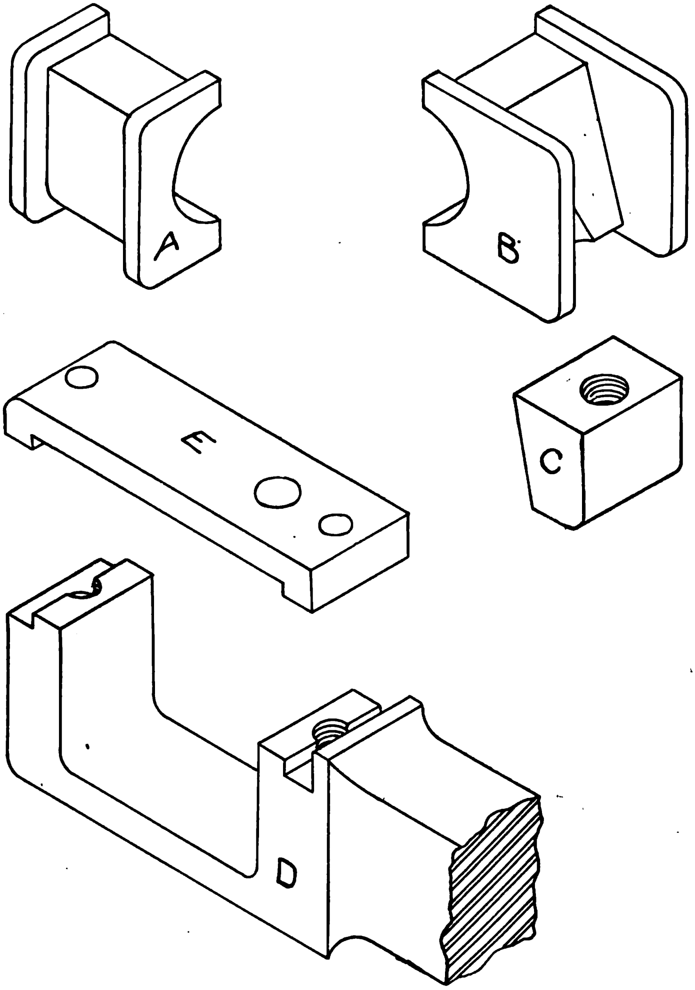


FIG. 117.—ISOMETRIC REPRESENTATION OF CONNECTING ROD PARTS

Fig. 118 is a detail drawing of the connecting rod shown in Fig. 115. In such drawings the parts are shown separately and represented by as many views as may be necessary to represent clearly every detail of the object. The several parts should be completely figured and with the necessary notes.

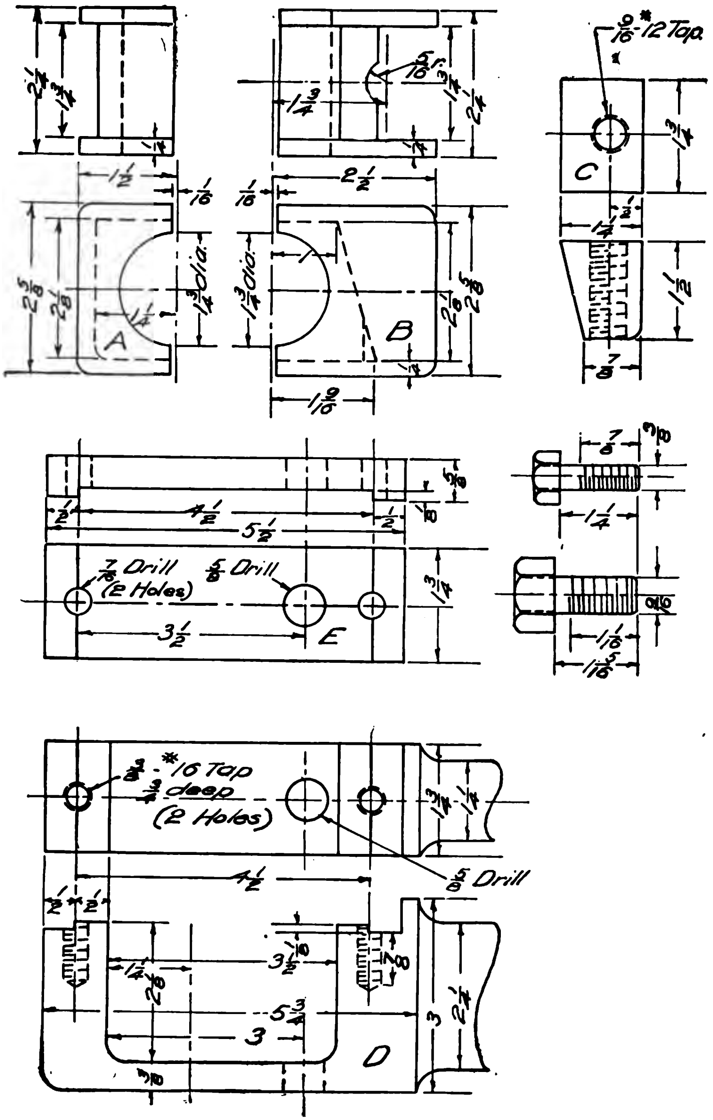


FIG. 118.—DETAIL DRAWING OF CONNECTING ROD END

Problems on Technical Reading and Expression

1. Trace the connecting rod drawing, Fig. 119, to make sectional views as follows:
   - *a.* The top view to be a section on a horizontal plane passing through the center.
   - *b.* The front view to be a section on a vertical plane passing throught the center.

2. Make an isometric representation of the parts similar to Fig. 117.

3. Make a detail drawing in projection similar to Fig. 118.

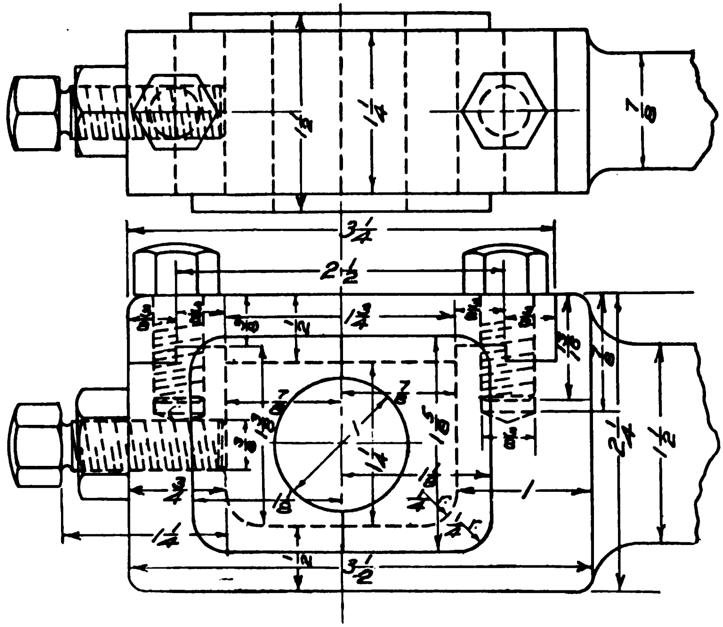


FIG. 119

4. Having completed problems 1, 2, and 3, make an assembly drawing like Fig. 119 but without reference to that illustration or to solutions 1, and 2, using only the detail drawing.

CHAPTER V

TECHNICAL SKETCHING

63. The Term Sketch usually signifies a freehand, instead of an instrumental rendering of Graphics. Technical sketches are made to serve several purposes, such as an aid to the recording of thought in the development of architectural and engineering ideas; to supplement the more laborious process of instrumental drawing when developing a design; to express thought when the written, or oral word, is insufficient to convey the complete idea, and this is of frequent occurrence; also, in the recording of existing construction, sketches are of the greatest value in that they may be made quickly, and by adding the necessary measurements may be made to serve the purpose of a more finished and expensive drawing.

64. A Notable Sketch. — While a sketch usually suggests incompleteness, it frequently includes much of detail. An admirable illustration of this type of sketch is that shown by the following Fig. 120, page 94, which is a reproduction of a page from the notebook of James Nasymth (1808–1890) a noted English mechanic, inventor. and scientist. It is the design for the first steam hammer ever constructed and is most remarkable in that the first machine was constructed from this sketch by a French manufacturing company without the knowledge of Mr. Nasmyth.

A brief statement of the facts relating to this sketch, and the building of the first steam hammer, is of value in emphasizing the importance of sketches and the necessity for accuracy in

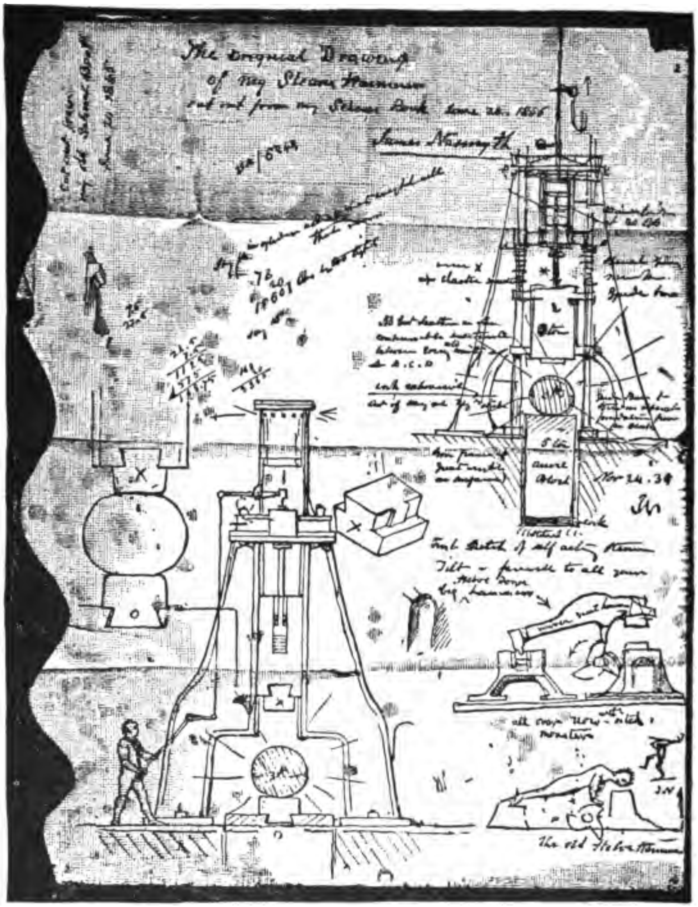


FIG. 120. FIRST DRAWING OF STEAM HAMMER BY JAMES NASMYTH
NOVEMBER 24, 1839
From the *Autobiography* published by Harper and Bros., New York.

expressing thought through this medium. A request having been made to Mr. Nasmyth for the forging of a shaft of greater size than could be made by any mechanical hammers then in existence, he proceeded to develop the idea of a new type of power hammer of which he writes the following in his autobiography:

> "Following up this idea, I got out my *Scheme Book*, on the pages of which I generally thought out, with the aid of pen and pencil, such mechanical adaptations as I had conceived in my mind, and was thereby enabled to render them visible. I then rapidly sketched out my Steam Hammer, having it all clearly before me in my mind's eye. In little more than half an hour after receiving Mr. Humphries' letter narrating his unlooked-for difficulty, I had the whole contrivance in all its executant details, before me in a page of my Scheme Book, a reduced photographed copy of which I append to this description."

The subsequent history of the sketch testifies to its remarkable completeness which the reduced size of the illustration fails to make clear. A short time after the making of this sketch, the order for the forging was canceled and the hammer was not built by the Nasmyth concern, but three years later Mr. Nasmyth chanced to visit a French engineering establishment and there beheld his steam hammer in operation. It had been designed from this original sketch, a copy of which had been loaned to the engineer of the French company by the partner of Mr. Nasmyth. The design of the hammer, which had been constructed without the knowledge of Mr. Nasmyth, was almost identical with his original conception which had been so completely expressed in the sketch, illustrated on page 94, as to make the construction possible.

65. Some Ancient Sketches. — In contrast to the previous sketch, it is interesting to note the character of one made by Leonardo da Vinci in which perspective is used as the medium of graphic expression. This sketch, Fig. 121, illustrates the graphic record of the development of the sprocket chain idea, which must be nearly 500 years old, according to this record.

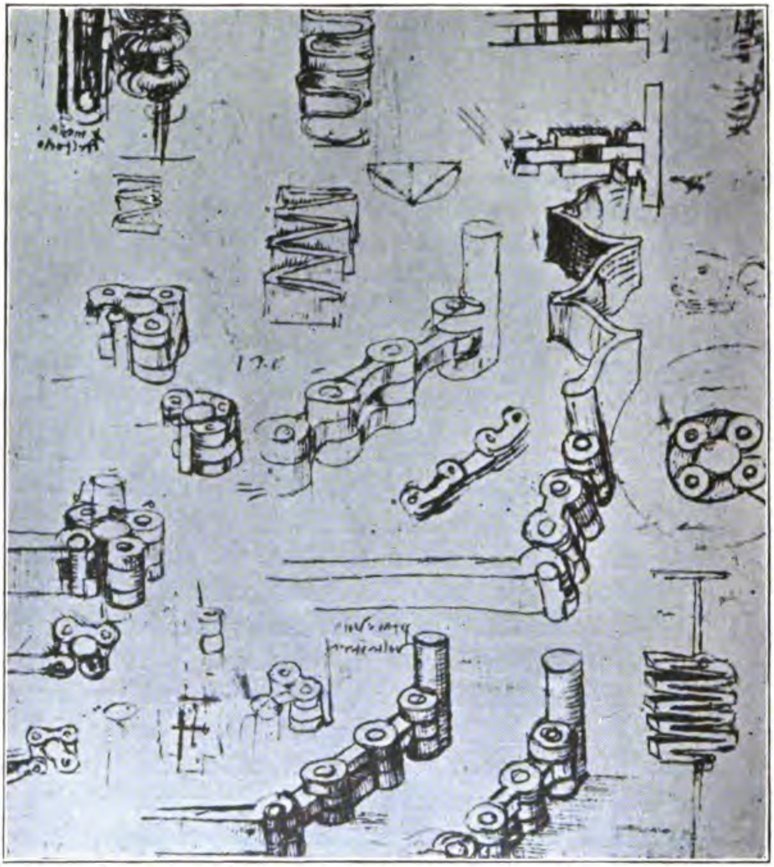


FIG. 121. SKETCH FOR SPROCKET CHAIN BY LEONARDO DA VINCI

Many of Leonardo da Vinci's sketches were works of art as evidenced by his design for a huge cross bow which has been much reduced in Fig. 122. The profession of military engi-

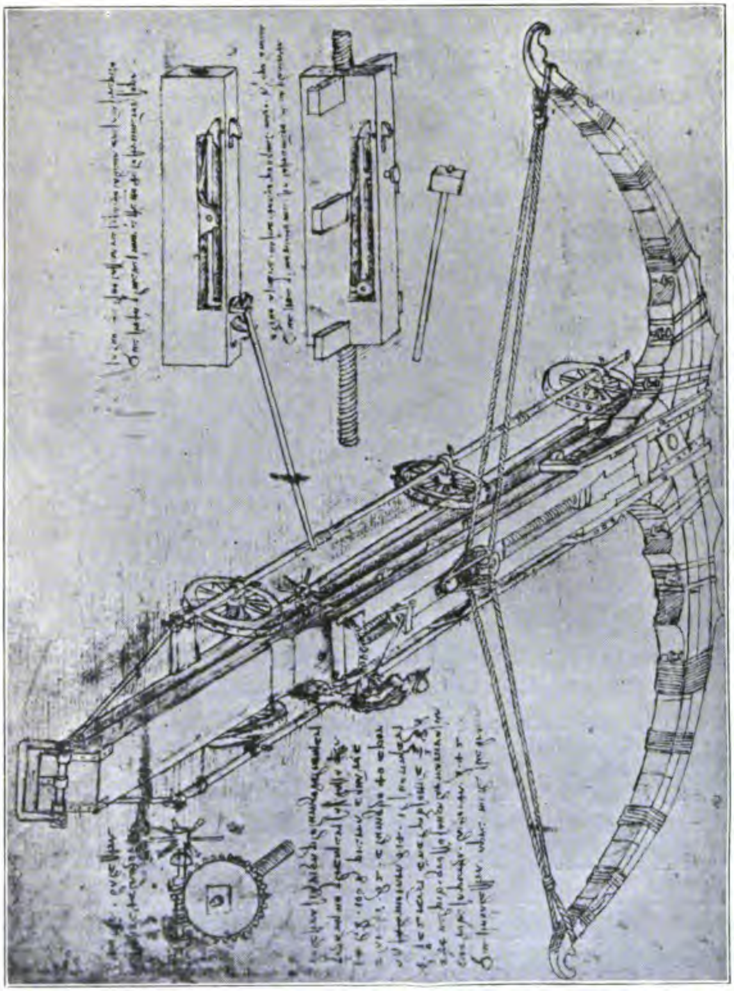


FIG. 122. REPRODUCED FROM A SKETCH BY LEONARDO DA VINCI (1452-1519)

neering was frequently coupled with that of fine arts and the great master, Michael Angelo, was called upon to design the means of defence for his city. Although little of the frescos and paintings of Leonardo da Vinci remain to this day, thousands of sketches and designs covering almost the entire field of mechanics are preserved and many have been reproduced and published. The most notable of these collections may be seen in the "Codex Atlantico" published in Milan and to be found in the large public libraries.

66. The Medium generally used in technical sketching is orthographic projection, and the rules governing the relation of the views should be observed as strictly as in the making of a finished drawing.

Perspective sketches are best adapted to the expression of ideas for those unaccustomed to reading Graphics, but there is considerable difficulty in making a good perspective sketch of a piece of mechanism.

Isometric representations, or other modifications of it, are good substitutes for perspective in freehand sketching, and very little practice enables one to become quite proficient. This is specially true if one makes use of cross section paper with isometric ruling. Rectangular cross section paper can also be used to great advantage in making sketches in orthographic projection.

Fig. 123 is a characteristic note book sketch for the cross-head of an engine. It may be used for making an assembly drawing, or for sectioning by a horizontal plane passing through the center. It also illustrates the use of sections in sketches.

67. Notes and Rules on Technical Sketching. — Skill in making readable sketches is not so much dependent on the clever handling of a pencil as in well directed thought and observation. One should use the most concise methods of graphic expression consistent with clearness, and observe the following suggestions:

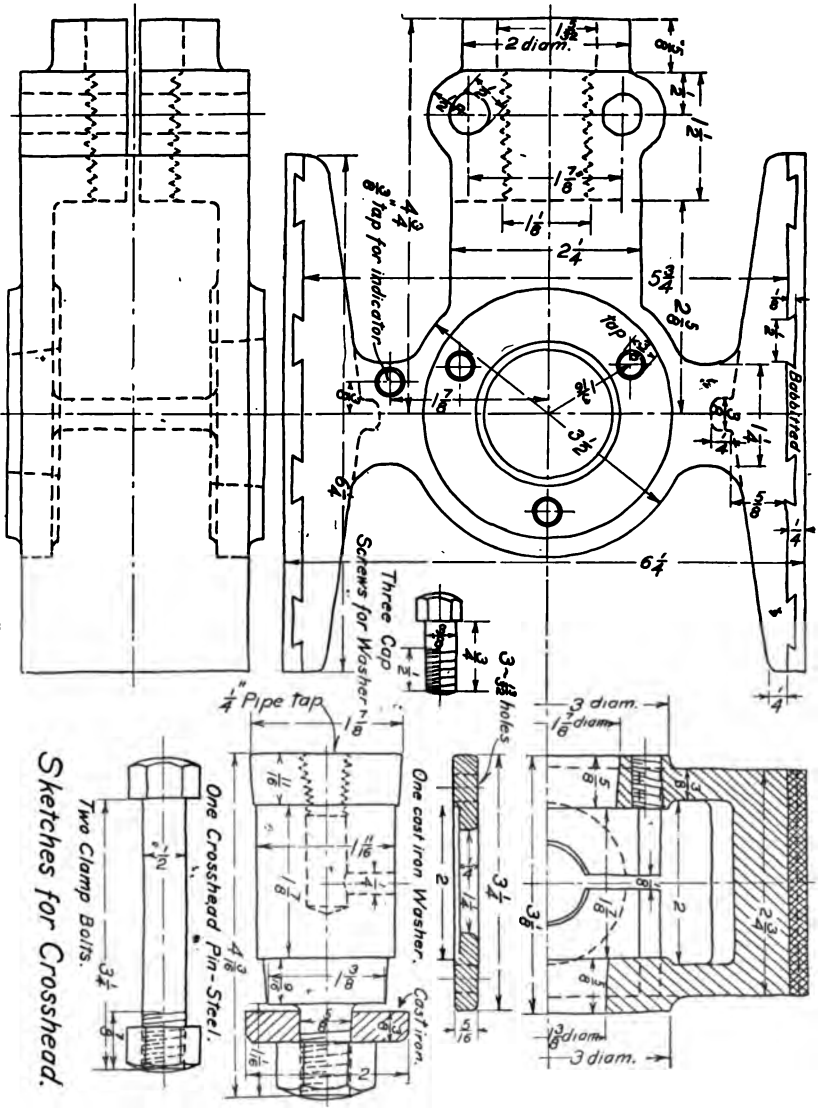

Sketches for Crosshead.
Two Clamp Bolts.
One Crosshead Pin-Steel.
One cast iron Washer.
Cast iron.
Three Cap Screws for Washer
1/4" Pipe tap
1/4" tap for indicator
tap
Babbitted
3- holes
2 diam.
3 diam.
1 7/8 diam.
1 3/8 diam.
3 diam.
2 1/4
5 3/4
2 5/8
3 1/2
6 1/4
4 3/4
1 7/8
1 1/8
3 1/4
3 1/8
4 3/16
2 3/4
3 1/4

FIG. 123

Economy in the use of lines is very important, hence the minimum number of views must be used.

The several views must be properly related according to the principles of orthographic projection.

Use parts of views to show special details.

Cylindrical pieces can usually be shown by a single view.

Use written notes when a view can be omitted thereby.

Use sections whenever they will add to clearness.

Section but a part of a view when that will suffice.

If possible, avoid views requiring the drawing of circles.

Do not overcrowd a sketch with details.

Draw center lines with care.

Maintain a close approximation to the proportions of the object sketched.

There are three divisions of the work required in making sketches from a piece of mechanism that must be strictly observed as follows: —

FIRST. — Separate the several parts of the mechanism and sketch each part separately.

SECOND. — Having completed all of the sketches, draw all the necessary dimension lines with their arrow points and witness lines.

THIRD. — Obtain the figures for the dimension lines as indicated on the sketch.

In most technical sketches the selection and placing of dimensions requires more experience and expert work than the making of the sketch, and while it is beyond the scope of this treatise to deal fully with these technicalities, it is very important to lay stress on this feature of a sketch.

CHAPTER VI

GRAPHICAL INTERPRETATION OF STATISTICS AND NUMERICAL RELATIONS

68. Graphical Statistics.—One of the simplest but very important uses of the Graphic Language is in the presentation of statistical data of various kinds. Any collection of related facts is difficult to grasp when expressed by figures in tabular form, but the same may be seen at a glance when presented by one of the many methods for the graphic representation of these ideas.

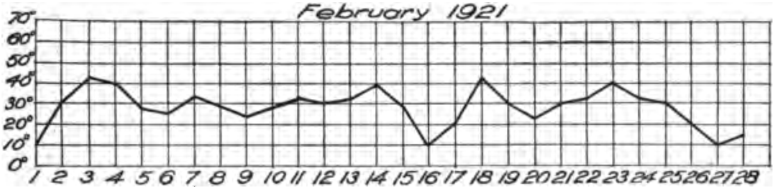


FIG. 124. DAILY MEAN TEMPERATURE FOR MONTH OF FEBRUARY

Day	Temp.	Day	Temp.	Day	Temp.	Day	Temp.
1	10	8	30	15	30	22	32
2	30	9	25	16	10	23	40
3	43	10	30	17	20	24	32
4	40	11	32	18	42	25	30
5	28	12	30	19	30	26	20
6	27	13	32	20	23	27	10
7	32	14	40	21	30	28	15

A simple illustration of this is in the temperature chart shown by Fig. 124 which records the daily mean temperature for one month with the tabulated data below. If the latter had been presented alone, it would have been necessary to read every figure to determine the dates of the maximum and minimum temperatures for the period considered, but a glance at the chart

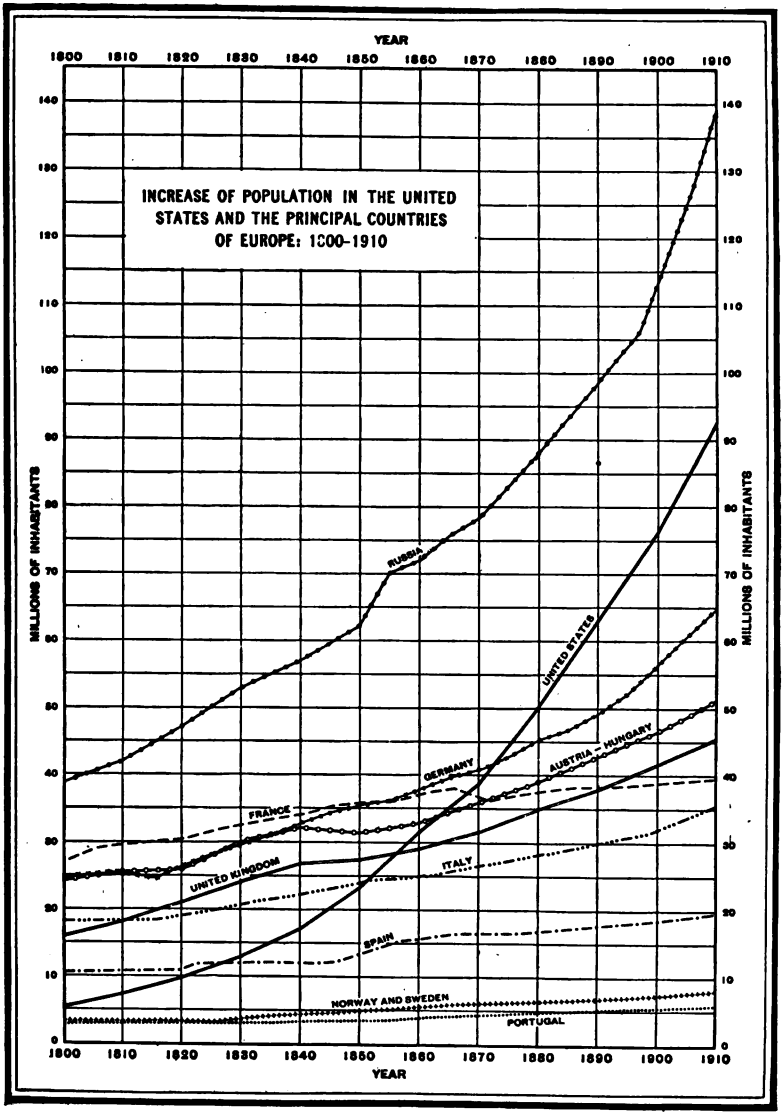


FIG. 125. RELATIVE INCREASE IN THE POPULATION OF TEN COUNTRIES.

enables one to quickly determine the high and low points of the curve and the corresponding dates. The variation in temperature, whether gradual or sudden, is clearly indicated without the labor of determining the numerical differences in degrees.

69. Coördinate Method. — In the preceding case, there were but two factors to consider, the temperature and date, but if there had been several related values to be considered, the difficulty of grasping the significance of their relations would have been greatly increased when presented in tabulated numerical form.

The diagram of Fig. 125 illustrates the relative increase in the population of ten countries for every decade from 1800 to 1910. The fluctuation and rate of increase in these values is apparent at a glance, and a difference in the character of the lines prevents the confusion which might be caused by the crossing of the lines. Note the steady increase in the population of the United States since 1870, also, the still greater increase in the population of Russia since 1898. Compare this with that of France since 1870, at which time the Franco-Prussian War was responsible for a considerable decrease in population.

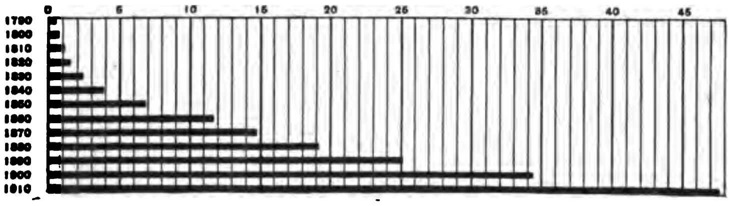


FIG. 126. POPULATION OF NEW YORK CITY IN HUNDREDS OF THOUSANDS

70. Values Expressed by Length of Lines. — Another method of graphically illustrating numerical values is shown by Fig. 126, which gives the increase in the population of New York City from 1790 to 1910. It would have been quite as well to have made this diagram in the form of a curve as in Fig. 125.

71. Varying Values for Successive Periods. — The method of relating three varying values for successive periods of time

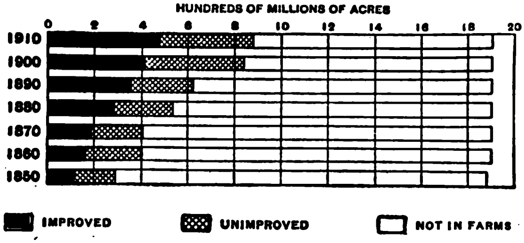


FIG. 127. TOTAL LAND AREA, ALSO IMPROVED AND UNIMPROVED LAND IN FARMS

is illustrated by Fig. 127, which gives the proportion of the total land area of the United States to the improved and un-

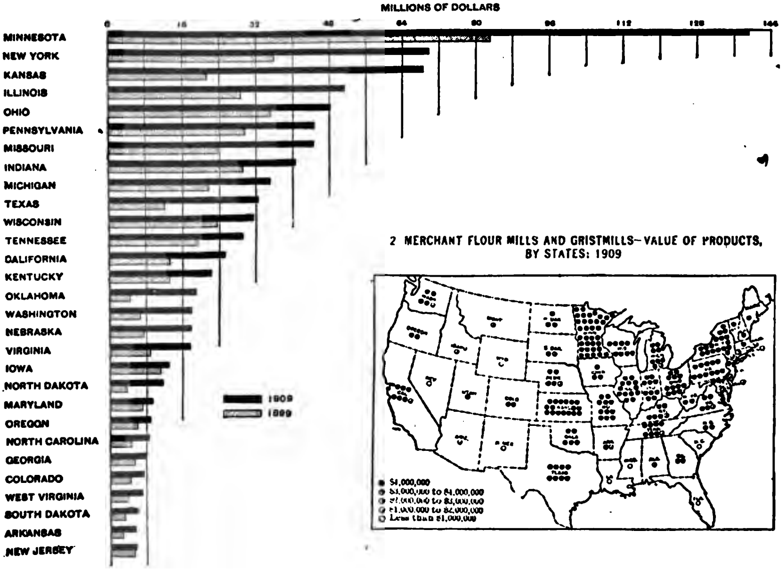


FIG. 128. MERCHANT FLOUR AND GRISTMILLS. VALUE OF PRODUCTS FOR LEADING STATES

improved land in farms. In this case a variation in the character of the line suffices to distinguish between the different factors.

72. Variations by Character of Lines. — Fig. 128 is an interesting graphic comparison of the value of the product of merchant flour in 29 states for the years 1899 and 1909 by the use of two lines of different character to distinguish between the dates, and the length of the lines representing the value of the

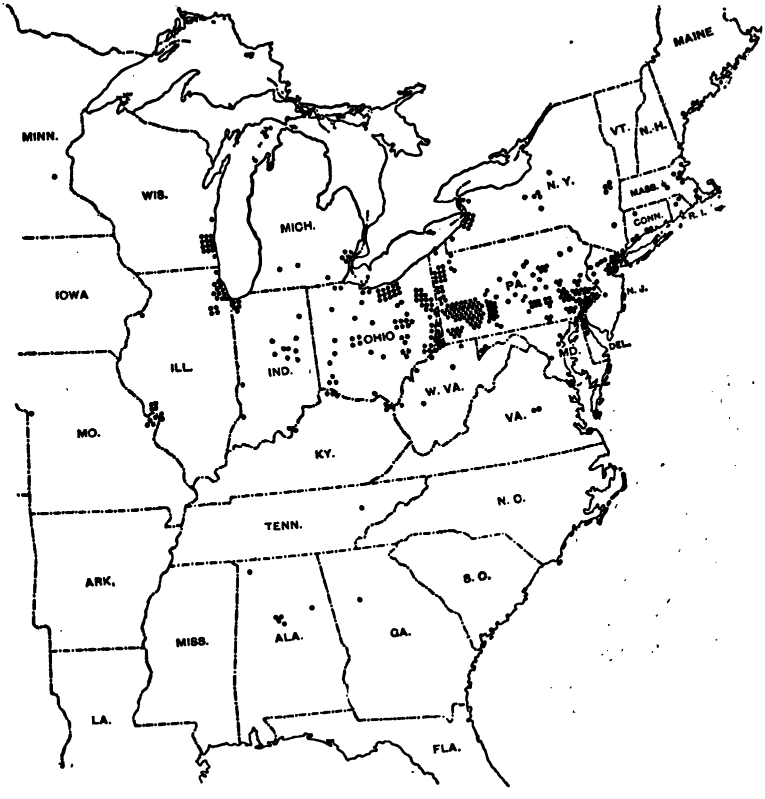


FIG. 129. STEEL WORKS AND ROLLING MILLS — LOCATION OF ESTABLISHMENTS, 1909

product in millions of dollars. It also illustrates the distribution of this product over the United States by the dots on the map of the several states. In reading the first diagram one does not realize that the flour producing states are chiefly East of the Mississippi, which the second diagram clearly shows.

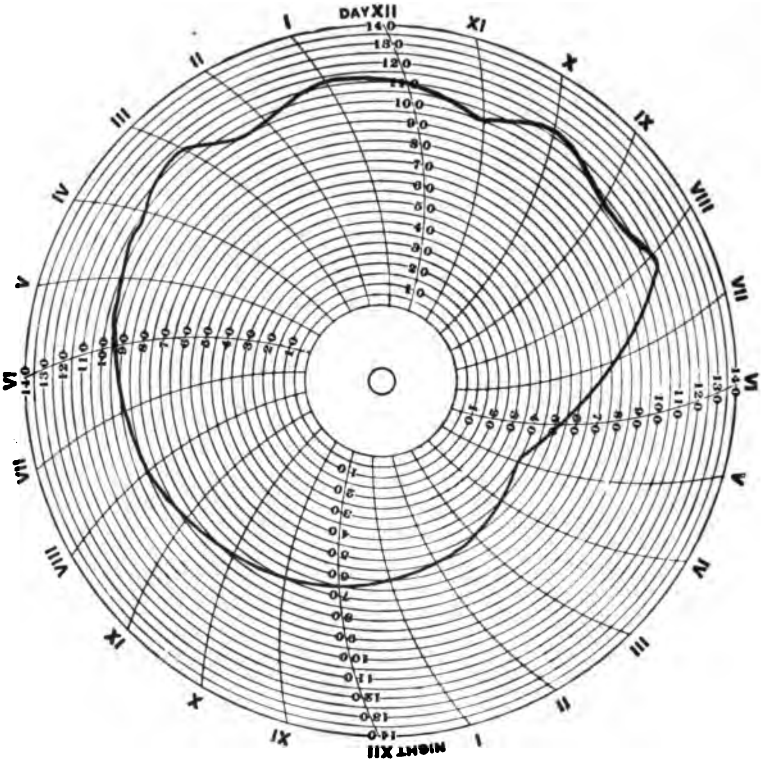


FIG. 130. RECORDING GAGE CHART

This last named method is much used for advertising purposes by showing the distribution of industries, manufactured products, agencies, or other interests throughout the United States. This information is recorded by placing pins in a map to indicate the number and location of the interests, as illustrated by the dots in Fig. 129 page 105.

73. Recording Gage Charts. — An entirely different type of chart from the preceding is illustrated by Fig. 130, which is typical of a great variety drawn automatically by recording instruments. In this chart there is recorded the varying pressures in a steam boiler for 24 hours. The fall in pressure during the night is clearly indicated together with any variations in pressure that may have taken place during the day. The time of firing the boiler in the morning is also indicated, and the management of the plant can see at once any failure on the part of the fireman to observe prescribed conditions.

74. Publications. — These diagrams are only suggestive of types which can be varied to meet the requirements of all possible statistical information, mathematical formulas, recording instruments, and indeed, every form of related data. An examination of the Statistical Atlas of the United States, from which most of the illustrations have been drawn, and which is published at intervals of ten years, will acquaint one with the extent to which this form of Graphics is applicable.

There are three books of importance to the student which approach the topic from three quite different standpoints, all of which have been published since 1914. The first of these is by Willard C. Brinton and entitled *Graphic Methods for Presenting Facts*. It is quite free from the mathemeatics of the subject and designed for a practical business treatment. The second, by Professor Joseph Lipka, *Graphical and Mathematical Computation*, treats the subject from the mathematical point of view and is directed especially to the student of engineering. The third, by William C. Marshall, M.E., C.E., entitled *Graphical Methods*, covers both of these fields and appeals to the business man and practicing engineers as well as the student.

75. Suggestions for the Graphic Representation of Data.—The most convenient and commonly used method is that by rectangular coördinates as shown by Fig. 125, page 102 when a curve is used to represent but two values.

1. In general the origin or beginning of the curve should be in the left hand lower corner, the figures for the horizontal scale being placed on the bottom of the chart, and those for the vertical scale at the left.
2. All lettering and figures should be placed so as to be read from the bottom and from the right of the chart.
3. In general the variable or determined value should be recorded on the vertical scale. Thus in Fig. 125 the population of the several countries is the variable, while the constant interval is recorded on the horizontal scale.
4. It is desirable that the minimum number of coördinate lines should be used in order to avoid confusion, but when a fine spacing is necessary, heavy lines may be introduced at regular intervals to assist the eye in reading the values.
5. Use a broader line for the curves than that for the coördinate ruling unless the characer of the line is distinctive.
6. In the representation of comparative area for statistical comparison, rectangular divisions are much better than the divisions of a circular area.

PART II

THE PENMANSHIP OF GRAPHICS

CHAPTER VII

INSTRUMENTS

76. Penmanship is of great importance in the efficient use of Graphic Language. Although one may acquire a good reading knowledge of Graphics by the use of freehand methods, especially with the aid of ruled paper, a knowledge of, and practice in, the use of instruments is necessary in order to rapidly and accurately interpret ideas through this medium. Natural aptitude for this mechanical work is not required for the making of good drawings, but the observance of a few fundamental principles is absolutely necessary.

Part II of this treatise is designed to give the essentials in the use of instruments, the geometrical operations necessary to the solution of the problems in Part I, and suggestions concerning lettering which shall enable one to avoid disfiguring an otherwise good drawing by written notes and figures which violate the laws of lettering.

77. The Minimum Outfit of instruments and material for a course in reading Graphics, such as described in Part I, should consist of the following: Two lead pencils, one of H grade for freehand sketching and lettering, and a 4H grade for geometrical and instrumental work; an eraser; two triangles, the minimum sizes of which should be, a 5″ 45° triangle, and a 6″ 60° triangle; a 12″ scale divided in sixteenths of an inch;

a pair of compasses provided with a so-called needle point, and a joint in each leg; one dozen small sized thumb tacks; cross section paper of about letter size, preferably ruled as in Figs. 131 and 132; and tracing paper of a good grade.

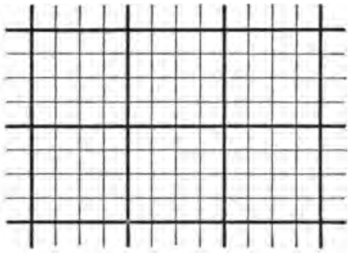


FIG. 131

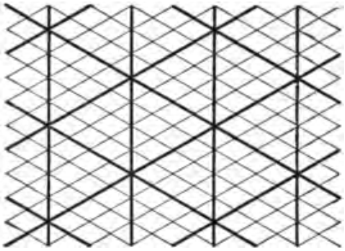


FIG. 132

If to the above a small board and T square be added, it will be possible to do a great variety of pencilled work, which is the only medium that should be required in an elementary course.

78. Freehand Use of the Pencil. — The H grade pencil is the best for use in freehand drawing such as is required for the solution of problems not necessitating instrumental work. It should be sharpened to a conical point exposing about $\frac{1}{4}''$ of lead. The wood should be removed by a knife, and the lead removed by means of a file, or sand paper, but never by a knife. A properly sharpened pencil is absolutely necessary to good work and rapid execution.

The pencil should be held as indicated in Fig. 133, not too tightly, but so as to give freedom in the motion of the fingers. The stroke, or motion, in drawing right lines may be by a succession of short strokes or by one continuous motion, the latter being the one more suitable for technical work. Lines should be drawn very lightly at first with a view to emphasizing them later if a correction is unnecessary. Indeed, most lines should be so lightly drawn at first that erasure may not be necessary.

79. Freehand Drawing of Right Lines. — If the required lines are to be parallel with the lower edge of the board or paper, they may be drawn freehand with the pencil held as in Fig. 133, and the stroke made in the following manner:

1. If the line be of considerable length, draw with a forearm movement with the arm resting on the elbow as a center.

2. If the line be a short one, draw with a freehand movement with the arm resting on the wrist as a center.

Both the above motions would result in making circular arcs if corrections were not made by a slight finger movement while drawing the line.

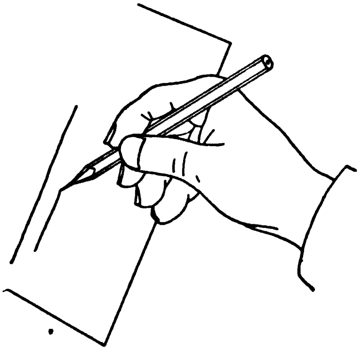


Fig. 133. Hand Holding Pencil for Horizontal Lines

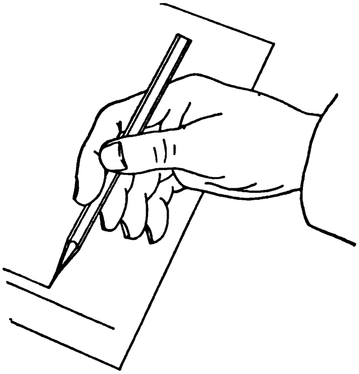


Fig. 134. Hand Holding Pencil for Vertical Lines

3. When the line is near, and parallel to the edge of the board, or paper, draw with the hand in the position of Fig. 133, and with the second or third fingers lightly touching the edge as suggested by the illustration.

4. If the lines are perpendicular to, or at a considerable angle with the lower edge of the board or paper, hold the pencil as in Fig. 134, and swing the pencil on the third joint of the little finger with the hand resting on the paper.

5. In drawing a line toward a given point, always keep the eyes on the point.

6. In drawing a line parallel to another line, always keep the eyes on the first line.

80. Freehand Drawing of Curves. — In general, draw a curved line with the hand on the concave side of the curve, changing the position of the hand, or the drawing, so as to make this possible.

Short arcs of circles of a large radius may be described by the forearm, or wrist motion, previously described.

If a freehand circle is required to be drawn with considerable accuracy, proceed as follows:

Draw two diameters at right angles thus estimating four points in the curve. At intermediate points in the curve, estimate four other points at the proper radial distance. Through these points describe the curve.

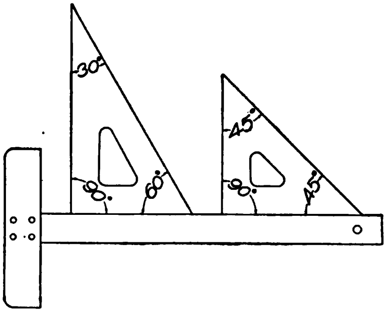


FIG. 135. T SQUARE AND TRIANGLES

81. The Use of Instruments. — Instruments are used in graphic writing for the purpose of obtaining a greater degree of accuracy and, if the drawing be complicated, for doing the work more rapidly. Those most commonly used for the drawing of right lines are: a 60° triangle, a 45° triangle, and a T square, all of which are shown in Fig. 135, and a 4H pencil sharpened to a chisel point as in Fig. 136.

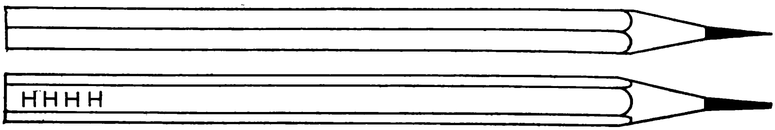


FIG. 136

Compasses are used for the drawing of circular arcs, two types of which are shown in Fig. 144, page 117, and to this one might well add a pair of dividers, Fig. 147, page 119.

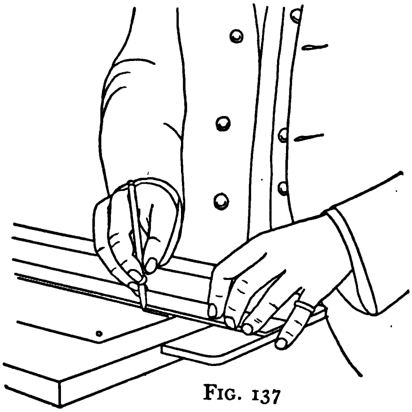


FIG. 137

82. The T Square is used for the drawing of lines parallel to the blade of the T square when the head is held firmly against the left hand edge of the drawing board, as in Fig. 137. The blade is fixed to the head with which it makes a right angle. It is also used with the triangles to serve as a base on which they can be slid for the purpose of drawing lines at various angles, and also perpendiculars to the T square blade. The position of the draftsman for the drawing of the latter is shown in Fig. 138.

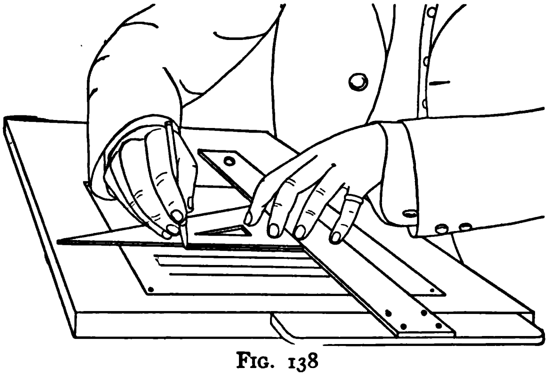


FIG. 138

The pencil is held in a nearly vertical position and pressed lightly against the upper edge of the blade. This gives freedom in the drawing of lines which would not be possible if the pencil point were crowded into the angle of the straight edge and paper, a condition which would be impracticable if ink were used.

83. The Triangles may be used with or without the T square. When the 45° and 60° triangles are used in combination with the T square it is possible to draw lines at angles of 15°, 30°, 45°, 60°, 75° and 90° to right or left of a perpendicular to the T square blade, as illustrated in Fig. 139.

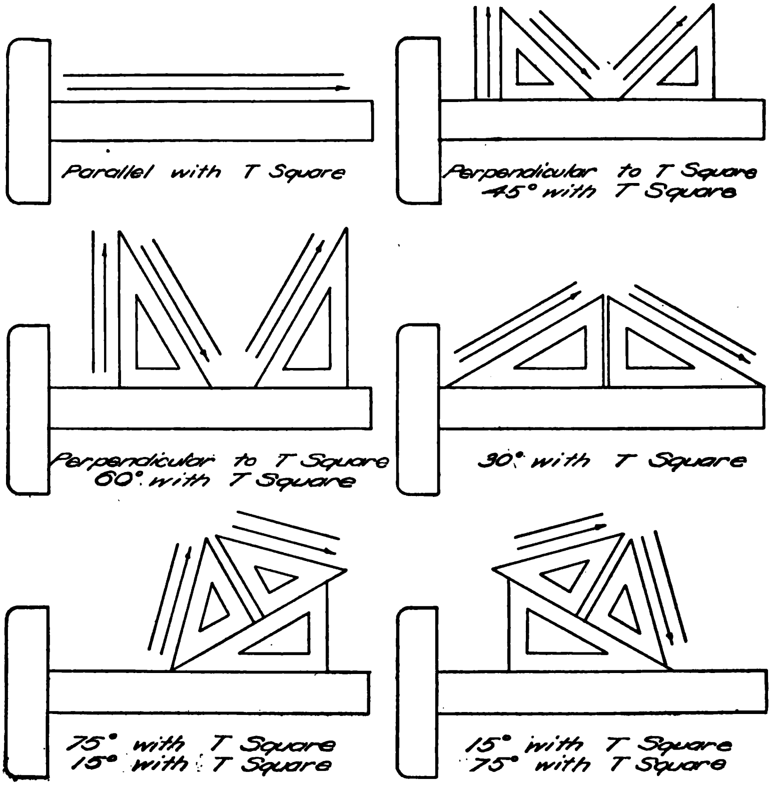


FIG. 139. COMBINATIONS OF T SQUARE AND TRIANGLES

When drawing perpendiculars to the blade the triangle should be held with the vertical edge to the left as in Fig. 138. This avoids a shadow being cast by the edge of the triangle, since the position of the draftsman should be such as to have the light received from the front and left of the drawing board.

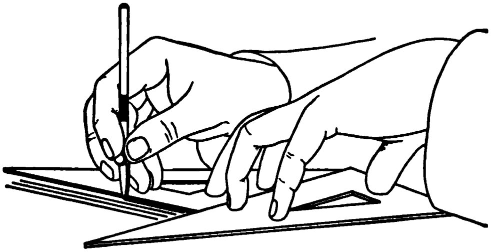


FIG. 140

Fig. 140 illustrates the method of drawing parallel lines at various angles without the aid of a T square. In this case, use care in holding the base triangle very firmly with the thumb and third and fourth fingers, while moving the second triangle by the first and second fingers.

To draw a line perpendicular to a given line by means of a pair of triangles, Fig. 141, place the hypothenuse of one triangle (1) parallel to the given line *AB* and in contact with the hypothenuse of the second triangle (2). Hold 2 and turn 1 through an angle of 90° (3). *CD* is the required perpendicular.

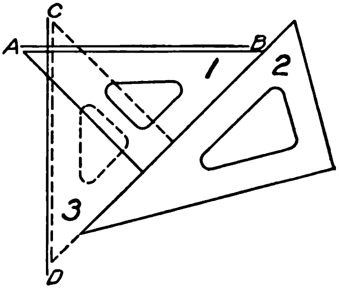


FIG. 141

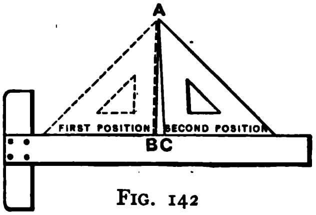


FIG. 142

84. To Test the Angles of Triangles. — The right angle may be tested as follows: Place the triangle on a straight edge, or T square, with the vertical edge at the right, as in Fig. 142, draw a fine line, *AB*, in contact with this edge, then reverse the triangle so that both edge and line may be free from shadow, and move the edge of the triangle toward the line. If they coincide, the angle is 90°. If they do not coincide, and the vertex of the angle formed by line and edge is at the top, as shown by *A*, the angle is greater than 90° by half the angle *BAC*. If the vertex of the angle is below, the angle is less than 90° by half the amount indicated.

Test of 45° Angle. — If the 90° angle is known to be correct, place the 45° triangle on the T square, as indicated by the dotted position, Fig. 143, and draw a line to coincide with the long edge. Reverse the triangle so as to bring the second acute angle into the position of the first, and if the edge coincides with the line drawn, the acute angles are equal and therefore 45°. If the line and edge intersect at the bottom, the angle of the triangle at this point of intersection is less than 45° by half the amount indicated by *AED*. If they intersect at the top, the angle of the triangle at this point is less than 45° by half the amount indicated.

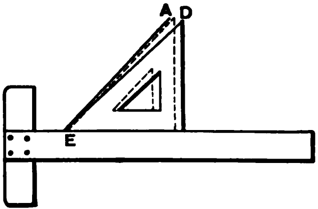


Fig. 143

Test of 30° and 60° Angles — If the 90° angle is known to be correct, draw a line to coincide with the T square blade, and from any point on this line construct an angle of 60°, as in Art. 94, page 128. Test the angle by sliding the short edge on the T square until the hypothenuse coincides with or intersects the line measuring the angle. If the 90° and 60° angles are found to be correct, the third angle must be 30°, since the sum of the angles of any triangle is equal to 180°.

85. Compasses and Their Use. — Fig. 144 illustrates two of the best types of instruments used for drawing circles and circular arcs. There are three removable parts: the pencil-point, pen-point, lengthening-bar, and in some of the cheaper instruments a plain point is added which can be used with the needle point to serve as dividers. There is a joint in each leg, and the removable leg is provided with a clamp screw. The shank of the removable parts should fit the socket closely, and require but a slight effort to remove. It should not drop from the socket, even though not clamped by the screw. All joints should work smoothly. The pen is similar in design to the ruling pen. Art. 88, page 121. The lengthening-bar is used to extend the pen or pencil-leg for the drawing of large circles.

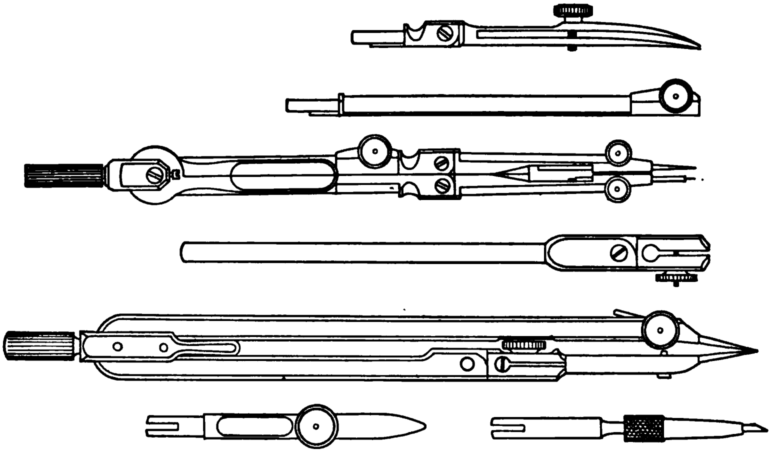


FIG. 144. COMPASSES

When first adjusting the compasses for use, place the pen-point in the instrument, pushing it firmly against the shoulder and securely clamp it. Adjust the needle-point so that its point coincides in length with the point of the pen, and if the compasses be used for circles of a radius less than $\frac{1}{2}''$, the needle-point should extend about $\frac{1}{64}''$ below the point of the pen. Once adjusted, the needle-point should not be changed. The needle-point is commonly made with a conical point at one end and a fine shouldered point at the other. The former should never be used, as it makes too large a hole in the paper. The alignment of the instrument may be tested by bringing the pen and needle-point together with the legs straight, and also when bent at the joints. The points should coincide in both instances.

To prepare the compasses for pencilling, place a 6H lead in the pencil-point, sharpening it to a chisel end as directed for the pencil, save that the length of the edge should not be more than $\frac{8}{64}''$. Next remove the pen-point from the compasses and replace it with the pencil-point. Adjust the length of the lead to coincide with the needle-point using great care to adjust the lead so that the direction of its edge shall be a tangent to the circle drawn, otherwise the width of the line will be greater than that of the chisel edge

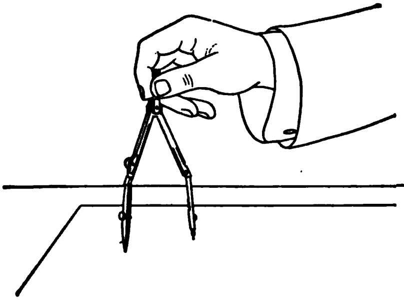


FIG. 145

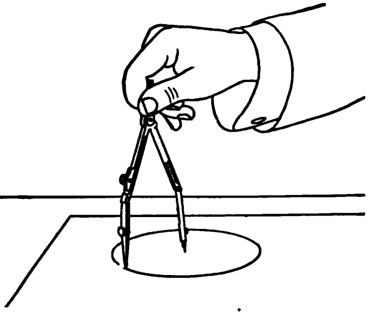


FIG. 146

The compasses are held between the thumb, first and second fingers, and rotated from left to right, clockwise. The hand must never be allowed to rest on the instrument, as the needle-point would be forced into the paper and the hole for the center made objectionably large. In placing the needle-point on a special center, the compasses may be steadied by lightly touching the point with a finger of the left hand. The point should be pressed lightly into the paper an amount sufficient to prevent slipping, but the hole should be scarcely visible. If it is necessary to designate it more clearly, sketch a pencilled line about it, but never put the point of the pencil into the hole to blacken it.

The needle-point must be kept vertical, and likewise the pen and pencil points.

Figs. 145 and 146 illustrate the method of holding the compasses, and the position of the fingers before and after the drawing of a circle.

In drawing a circle, stop the line as soon as the circumference is completed, otherwise the line may be widened. If several arcs are to be drawn from one center it is better to remove the needle-point from the center when changing the radius, as the hole may become badly worn if much pressure is exerted against it. The directions for cleaning and filling the pen are the same as for the ruling-pen, Art. 88.

When using the lengthening-bar steady the needle-point with the left hand while moving the marking-point with the right. It is necessary to use care in doing this so as not to change the radius.

86. Dividers. — This instrument is similar in design to the compasses, but the legs are fixed, and without joints. It is used to transfer measurements from one part of a drawing to another, but must not be employed for transferring from a scale to the paper. It is also used to divide a line into any number of equal parts when the divisions cannot be obtained directly from the scale.

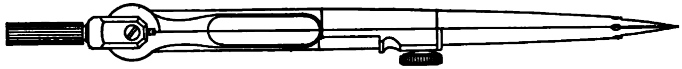


FIG. 147. DIVIDERS

Fig. 147 illustrates a pair of hair-spring dividers. The thumbscrew is used to obtain a more delicate adjustment. The ends of the legs should be conical rather than triangular, and must be kept sharp. The puncture made by the divider points should be extremely small, but sufficiently clear to be readily seen.

87. Bow Instruments. — These are used for the drawing and spacing of small arcs such as are described with difficulty by the compasses and dividers.

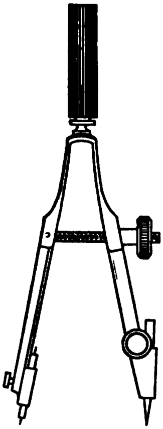


FIG. 148

THE BOW PENCIL, Fig. 148, should have the lead sharpened to a chisel edge but reduced nearly to a point so that a circle of $\frac{1}{32}''$ radius can be drawn with a fine sharp line. In adjusting the instrument for varying radii, it is well to press the points together by the thumb and finger thus releasing the tension on the adjusting screw and preventing wear in the thread of the nut. This instrument is commonly used for arcs of less than $\frac{1}{2}''$ radii.

THE BOW PEN. — Fig. 149. The range of this instrument, and its adjustment, is like that of the bow-pencil. In cleaning and filling the pen the same care must be used as described for the ruling-pen, Art. 88. An excellent test for the setting of the needle-point is as follows: Having adjusted it so that it projects slightly below the point of the pen, draw circles with the minimum radius of the instrument. If there is a tendency to lift the point from the paper, it is too short; but if it is difficult to draw the line without forcing the point into the paper, it is too long.

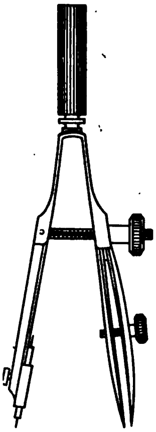


FIG. 149

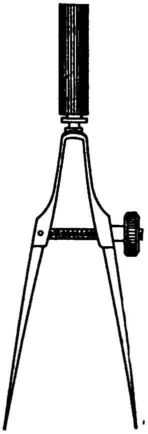


FIG. 150

THE BOW SPACERS, Fig. 150, are used like the dividers for the spacing of distances, but they have the advantage of being fixed in position so that there is no liability of a change in the space by the handling of the instrument. In spacing distances the instrument is rotated alternately right and left, as in the case of the dividers, Fig. 153, and the forefinger should rest on the top of the spacers to steady them.

88. The Ruling-Pen. — Fig. 151 is an enlarged view of the instrument which is used for the inking of all lines other than circular arcs. The nibs must be of equal length, rounded alike, and equally sharp. The pen is filled by inserting the ink between the nibs with a common writing pen, or the quill that is furnished with many of the bottled inks. The nibs should be opened slightly to admit the ink freely. This method of filling should not necessitate wiping the outside of the nibs, but great care must be used to insure their being perfectly clean. Do not overload the pen, $\frac{1}{4}''$ of ink being sufficient for the ordinary pen. Having filled the pen, nearly close the nibs and try the width of the line on a piece of paper, opening or closing the nibs by means of the screw to vary the width of the line.

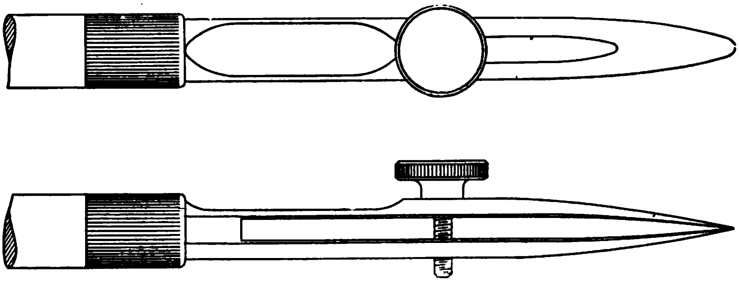


FIG. 151

The pen should be held by means of the thumb, first and second fingers, the thumbscrew being held from the body so as to be readily adjusted by means of thumb and second finger. Its position should be nearly vertical, being inclined slightly to the right. See Fig. 137. The pen should touch the straight edge lightly as too much pressure will reduce the space between the nibs and cause an unevenness in the line. If both nibs touch the paper, the line should be equally clean and sharp on both edges, but if they do not touch the paper, because of their being of unequal length, or because the pen is inclined from or toward the body, the line will appear ragged on one edge. If the distance between the nibs be unchanged the width of the line should remain constant. As the ink dries very rapidly, causing a slight deposit between the nibs, the width of the line will be reduced unless care is used to clean the nibs frequently, for which purpose a penwiper should always be at hand. If the ink fails to flow freely, touch the point lightly to the penwiper, or the drawing board, and it will dislodge the small deposit at the point which prevents the flow. If this fails, clean the pen thoroughly, and refill. Never lay the pen aside without cleaning.

All first-class pens are properly sharpened when new, but with the cheaper qualities this is not commonly the case. The most frequent defect is in an insufficient rounding of the point.

An excellent test for the ruling-pen is as follows: Having filled the pen, adjust it to draw a fine line, and without the aid of a straight-edge draw a number of lines with the pen inclined more and more from the body until the inner nib is raised sufficiently high to prevent the drawing of a line. Repeat this operation with the pen inclined toward the body. If the angles at which the last line is drawn in each case are equal, the nibs are of equal length. Next draw lines with the pen inclined to the right and to the left about 45°. If the pen moves freely, and draws clean, sharp lines, the point is sufficiently rounded. If the pen is too sharp, the cutting of the paper can easily be detected by the touch.

Questions on the Use of Instruments

1. For what purpose is the T square used?
2. Is it necessary that the blade be exactly at right angles with the head?
3. How is a pencil or pen held when drawing lines with the edge or blade of the T square?
4. Describe the two triangles most commonly used.
5. If a 45° triangle be used on the blade of a T square, how many different angles may be drawn? Name them.
6. If a 60° triangle be used on the blade of a T square, how many different angles may be drawn? Name them.
7. If the 45° and 60° triangles be used in combination with the T square, how many different angles may be drawn? Name them.
8. Sketch the position of the combined triangles and T square for drawing lines inclined to the right and at 75° with the T square.
9. Sketch the position of the combined triangles and T square for drawing lines inclined to the left and at 15° with the T square.
10. How is the right angle of a triangle tested?
11. How are the 45° angles tested?
12. How are the 30° and 60° angles of a triangle tested?
13. How may a perpendicular to a given line be drawn by the use of triangles only?
14. How should the light fall on the work to obtain the best results in using the triangles and T square?
15. For what purposes are dividers used?
16. In what respect do the dividers differ from compasses?
17. Describe every operation necessary to preparing a new pair of compasses for pencilling circles.
18. What is the function of the needle point? Sketch one.
19. What precautions should be used to prevent the enlargement of a center about which circles are being drawn?
20. In what direction should the compasses be revolved?

21. Why are joints provided in both legs of the compasses?
22. What instruments are used for the drawing of very small arcs and circles?
23. Why are the blades of a ruling pen rounded instead of pointed?
24. How is the flow of the ink in a ruling pen regulated?
25. What precautions should be observed to maintain a uniform width of line?
26. How may the pen be tested?
27. If one side of an inked line presents a ragged appearance, what defect in the pen or the holding of the pen is indicated?
28. How should the ruling pen be held?
29. Draw a considerable number of lines radiating from one point and note the effect produced by the slightest failure to pass through the point.
30. Draw a number of circles tangent to each other at one point and note the effect produced by the slightest inaccuracy.
31. Determine by trial the number of concentric circles which can be drawn without visibly enlarging the center.
32. Divide a circle into 15° angles by means of two triangles and the T square.

CHAPTER VIII

APPLICATIONS OF GEOMETRY TO GRAPHIC PENMANSHIP

89. Geometrical Principles. — This chapter includes the essential geometrical principles necessary to the solution of the problems of Part I.

In many cases two methods of construction are illustrated, one being the ordinary geometrical solution by straight edge and compasses, and the other being the draftsman's method by T square and triangles.

Familiarity with these problems will greatly facilitate the study of Graphics by the ready use of instruments, and if to this be added that of accuracy in drawing, a great saving in time will be effected.

90. To Divide a Line Into Any Number of Equal Parts. — Let AB, Fig. 152, be the given line and the required number of divisions be five.

Method by Scale or Dividers. — Draw AC at any angle with AB and on it lay off five equal spaces of any length by the dividers, or scale. Connect the last point, 5, with B, and draw parallels through the other points intersecting AB in points 1′, 2′, 3′, and 4′ which determine the required divisions of AB.

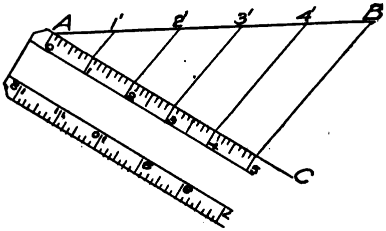


Fig. 152

TRIAL METHOD. — Fig. 153. Open the dividers to a distance equal to $A1$, about one-fifth of the required space, and holding them at the joint by the thumb, first and second fingers, place one point at A, the extremity of the line to be divided, the other point being at 1. By rotating the instrument in opposite directions, as though describing a series of semicircles, lay off divisions $A1$, 1 2, 2 3, 3 4, 4 5. Point 5 being beyond the extremity of the line, the divisions are too great, and should be diminished by an amount equal to one-fifth of $B5$. Make a second, or third trial, if necessary, so that the last division shall fall on B. If the required number of divisions be even, bisect the given line, then bisect these divisions, and so continue until the required number be obtained.

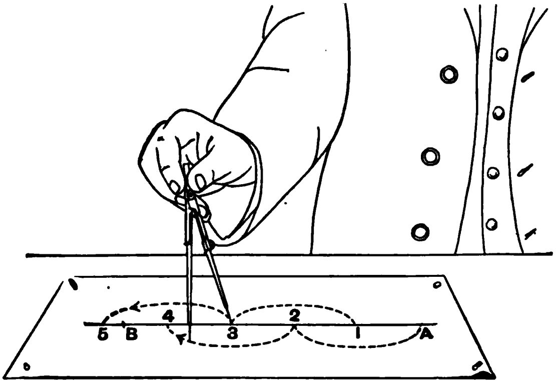


FIG. 153

91. To Bisect a Right Line, AB, the Arc of a Circle, or an Angle ACB. — Fig. 154. With centers A and B, and any radius greater than one-half of AB, describe arcs 1 and 2. Through the points of intersection of these arcs draw a line. Its intersection with the given line AB, or the arc of the circle ACB, will determine the required points.

DRAFTSMAN'S METHOD. — Obtain the division with the dividers as explained in Art. 90.

92. To Draw a Perpendicular to a Line *AB*. Case 1. — **Fig.** 155. When the given point *C* is on the line. From *C*, with any radius, draw arcs 1 and 1, and from the point of intersection of these arcs with *AB*, with any radius greater than arc 1, draw arcs 2 and 3. The line drawn through the point of intersection of these arcs and the point, *C*, will be the required line.

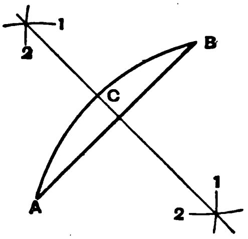


Fig. 154

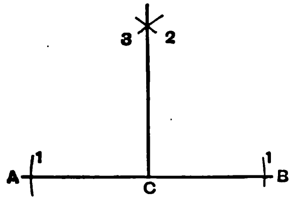


Fig. 155

Case 2. — Fig. 156. When the point is outside of the line. From *C*, with any radius, describe arcs 1. From the point of intersection of these arcs with *AB*, and with the same radius, describe arcs 2 and 3. A line drawn through this point of intersection and the given point *C*, will be the required line.

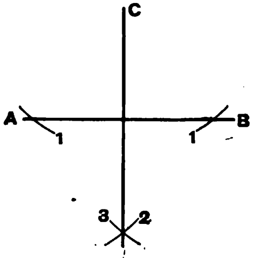


Fig. 156

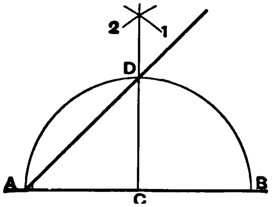


Fig. 157

93. To Construct an Angle of 45° with *AB* at Point *A*. — Fig. 157. Through the given point, *A*, describe a semicircle on *AB*. Draw a perpendicular through the center *C*. A line drawn through the point *A* and intersection of the perpendicular with the semicircle will make an angle of 45° with *AB*.

94. To Construct Angles of 60°, 30° **and** 15° **with** *AB*.—Fig. 158. From the given point *A* as a center, with any radius, describe arc 2. From *B*, with the same radius, describe arc 3. A line drawn through *A* and this point of intersection will make an angle of 60° with *AB*.

Through the given point *A*, describe a semicircle on *AB*. With same radius, from *C* describe arc 1. The line drawn through *A* and this point of intersection makes an angle of 30° with *AB*.

Having constructed an angle of 30°, as described, bisect the same, and *FAB* will be the required angle of 15°. In this case it would not be necessary to draw the 30° line.

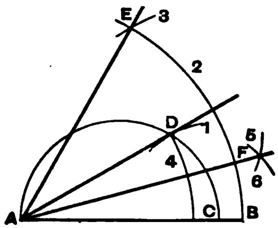


Fig. 158

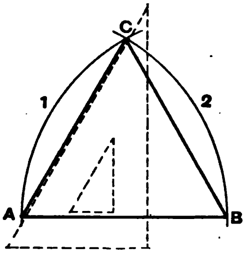


Fig. 159

95. To Construct an Equilateral Triangle Having Given the Side *AB*.—Fig. 159. Since the sides are equal, the angles will be equal, and therefore, 60°, the sum of the angles of any triangle being equal to 180°. With centers *A* and *B* and radius *AB*, describe arcs 1 and 2. From the point of intersection, *C*, draw *AC* and *BC*.

Draftsman's Method. — *AB* being drawn with the T square, through *A* and *B*, with 60° triangle, draw *AC* and *BC*.

96. To Circumscribe a Circle About a Given Triangle, *ABC*. — Fig. 160. Bisect two of the sides, as *AC* and *BC*. The point of intersection of these lines will be the center of the required circle. Draw a circle through *A*, *B*, and *C*. This problem is identical with that of drawing a circle through three given points, *A*, *B*, and *C*, not in the same right line.

97. To Inscribe a Circle Within a Given Triangle, ***ABC*.** — Fig. 161. Bisect two of the angles, as *CAB* and *ABC*. The point of intersection of these lines, *D*, will be the center of the required circle which will be drawn tangent to *AC*, *CB*, and *AB*.

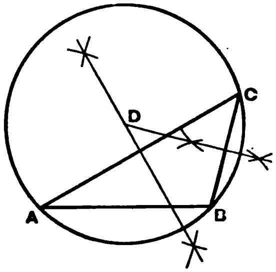


FIG. 160

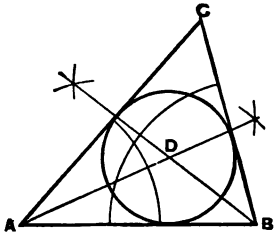


FIG. 161

98. To Inscribe an Equilateral Triangle Within a Circle. — Fig. 162. From the point *C* draw arc 1 with a radius equal to that of the circle. From its intersection with the circle, and with the same radius, draw arc 2. From center *C*, and with chord *CB* as a radius, describe arc 3, and connect points *A*, *B*, and *C*, which will give the required triangle.

DRAFTSMAN'S METHOD. — From point *C*, on the vertical diameter *CD*, draw *CA* and *CB* with the 60° triangle. With the T square draw *AB* to complete the triangle.

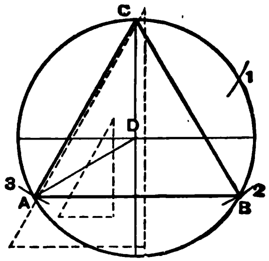


FIG. 162

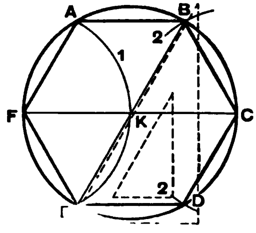


FIG. 163

99. To Inscribe a Hexagon Within a Circle. — Fig. 163. Draw diameter *FC*. With centers *F* and *C*, and radius equal to that of the circle, draw arcs 1 and 2. Connect the points of intersection *A*, *B*, *C*, *D*, *E*, and *F* to obtain the hexagon.

Draftsman's Method. — Draw a horizontal diameter *FC*. With 60° triangle draw diameter *EB*. Draw *AB* and *ED*, and with triangle draw *BC*, *FE*, *AF*, and *CD*.

100. To Circumscribe a Hexagon About a Circle. — Fig. 164. Draw any diameter, *AD*. With *H* as a center and radius equal to that of the circle, describe arc 1. Bisect the arc *HLN*, and through *L* draw *AB* parallel to *HN*. With center *K* and radius *AK* describe circle *ACE*. Inscribe a hexagon by Art. 99.

Draftsman's Method. — With 60° triangle draw diameters *AD* and *EB*, and with same triangle draw sides *AB* and *ED*, *EF* and *BC*, *AF* and *CD*, each tangent to the given circle.

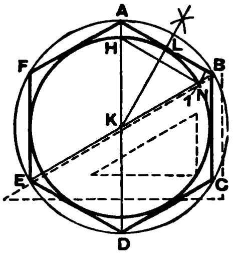


Fig. 164

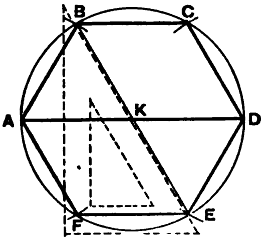


Fig. 165

101. To Draw a Hexagon Having Given a Long Diameter, *AD*. Fig. 165. Bisect *AD*. With *K* as center, describe circle *ACE*, and in this inscribe a hexagon by Art. 99.

Draftsman's Method. — With dividers find center *K*. Through *A* and *D* with 60° triangle draw *AB* and *DE*. With same triangle draw *BE*, and through *D* and *A* draw *CD* and *AF*. Draw *BC* and *FE* to complete the hexagon. To obtain *B* without finding *K* draw a line through *D* at an angle of 30° with *AD* intersecting a 60° line through *A*.

102. To Draw a Hexagon Having Given a Short Diameter, *GH*. — Fig. 166. Bisect *GH*. From *G* draw a perpendicular

GF. From *K* draw *FKC* at 30° with *GK.* Through *F* and with center *K* draw circle *FBD.* Inscribe a hexagon by Art. 99.

Draftsman's Method. — With dividers find center *K.* With 60° triangle draw *FC,* and through *G, K,* and *H* draw perpendiculars *FE, AD,* and *BC.* Draw the sides *FA, DC, AB, DE.*

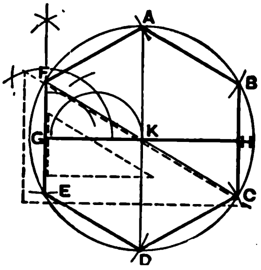
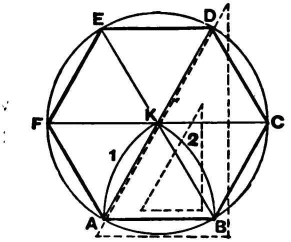


Fig. 166



IG. 167

103. To Draw a Hexagon Having Given a Side, *AB*. Fig. 167. With centers *A* and *B,* and radius *AB,* describe arcs 1 and 2. From their intersection, *K,* with same radius describe circle *AEC.* Inscribe a hexagon by Art. 99.

Draftsman's Method. — Through *A* and *B* with 60° triangle draw *AD* and *BE,* and through their intersection, *K,* draw *FC.* Draw *FA, BC, FE, DC,* and *ED.*

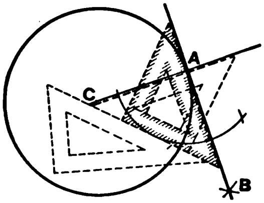


Fig. 168

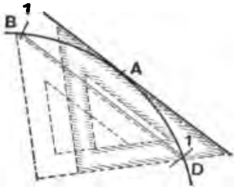


Fig. 169

104. To Draw a Tangent, *AB*, to a Circle.

Case 1. — When the given point *A* is on the circle. Fig. 168. Draw the radius *AC,* and erect a perpendicular, *AB* at *A.*

Draftsman's Method. — By means of two triangles draw *AB* perpendicular to *AC.*

Case 2. — When the point is on the circle and the center not accessible. Fig. 169. From the given point *A*, with any radius, describe arcs 1 and 1. Place the edge of the triangle to coincide with points *B* and *D*. Draw a parallel line through *A*.

Case 3. — When the given point, *B*, is without the circle. Fig. 170. Two tangents may be drawn. On *BC* as a diameter, describe arc 1; its intersection with the circle at *A* and *D* will be the points of tangency. The angle *BAC*, inscribed in the semicircle, will be 90°.

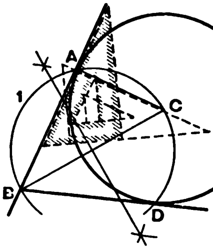
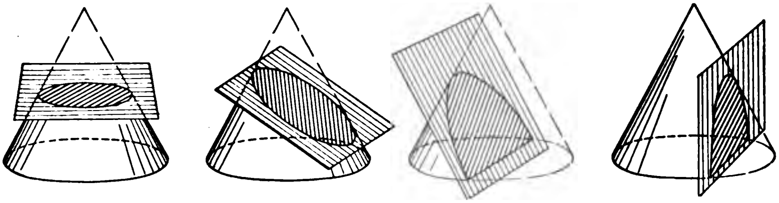


Fig. 170

Draftsman's Method. — From the given point, *B*, draw *BA* touching the circle. Through the center, *C*, draw a perpendicular to *AB*. *A* will be the point of tangency. In like manner obtain *BD*.



Circle Ellipse Parabola Hyperbola

Fig. 171

105. The Sections of a Cone.—If a cone be cut by planes in the manner illustrated by Fig. 171, curves will be obtained which are known as Conic Sections, and have a very important application in the writing of Graphics. The second of these curves, known as an ellipse, is the curve of the foreshortened circle which appears in perspective, and frequently occurs in projection. The parabola and hyperbola are less used by draftsmen but a knowledge of their characteristics is very desirable.

106. The Ellipse is a curve generated by a point moving in a plane so that the sum of the distances from this point to two fixed points shall be constant. If, in Fig. 172, we conceive *EKF* to be a cord fastened at its extremities, *E* and *F*, and held taut by a pencil-point at *K*, the point will be constrained to move in a fixed path dependent on the length of the cord. When the pencil-point is at *B*, one segment of the cord will equal *BE* and the other *BF*, their sum being the same as *KE* plus *KF*, and also equal to *AB*. The fixed points *E* and *F* are called the FOCI. They lie on the longest line that can be drawn terminating in the curve of the ellipse. This line is known as the MAJOR AXIS, and the perpendicular to it at its middle point, also terminating in the ellipse, is the MINOR AXIS. Their intersection is called the center of the ellipse, and lines drawn through this point and terminating in the ellipse are known as DIAMETERS. When any two diameters are so related that a tangent to the ellipse at the extremity of one is parallel to the second, they are called CONJUGATE DIAMETERS. *KL* and *MN* are such diameters.

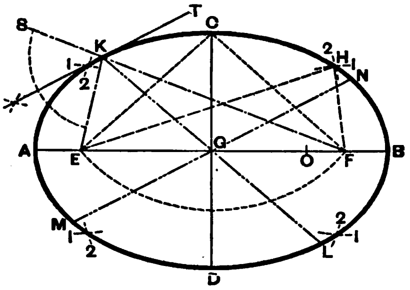


FIG. 172. ELLIPSE

In order to construct an ellipse it is necessary that either of the following be given: The major and minor axes; either axis and the foci; two conjugate diameters; a chord and axis.

107. The Ellipse. String Method. — Fig. 172. The major axis and foci being given, points in the curve may be determined as follows: From *E*, with any radius greater than *AE* and less than *EB*, describe an arc. From *F*, with a radius equal to the difference between the major axis and the first radius, describe a second arc cutting the first. The points of intersection of these arcs will be points, the sum of which distances from the foci will equal the major axis, and therefore points of an ellipse. Similarly find as many points as may be necessary to draw the curve freehand. Lightly pencil a line through these points.

If the major and minor axes be given, determine the foci by describing from *C* as a center, an arc with a radius equal to one-half the major axis. The points of intersection with the major axis will be the foci.

Again, if the major axis and foci be given, determine the minor axis by describing from the foci arcs with a radius equal to one-half this axis cutting the perpendicular drawn at the middle point of the major axis and thus obtain the minor axis. Having the two axes proceed as before.

A TANGENT to an ellipse may be drawn at any point, *K*, by connecting this point with the foci, and bisecting the exterior angle *SKE*. *KT* will be the required tangent.

108. The Ellipse. Method by Trammels. — Fig. 173. Lay off on a piece of paper having a clean-cut edge the distance *RT* equal to one-half the major axis, and *RS* equal to one-half the minor axis. If point *T* be placed upon the minor axis and point *S* upon the major axis, and the paper constrained to move always under these conditions, the point *R* will describe an ellipse. Points may be laid off on the drawing to correspond with the different positions of *R*, and through these the required ellipse will be drawn. This is an excellent method, as construction lines are not required. It is known as the method by trammels, since an instrument called the elliptographic trammel is constructed on this principle.

109. The Ellipse. Concentric Method. — Fig. 174. On the major and minor axes as diameters describe circles. Draw any radial line, as *MG*. From its intersection with the outer circle draw *MO* perpendicular to the major axis, and from its intersection with the inner circle draw *NO* perpendicular to the minor axis. The intersection of these lines at *O* will be a point in the ellipse. Similarly obtain other points.

110. The Ellipse. Parallelogram Method. — Figs. 175, 176, 177. This is a very general method and may be used when we have given either the major and minor axes, one of the axes and a chord of the ellipse, or any two conjugate diameters.

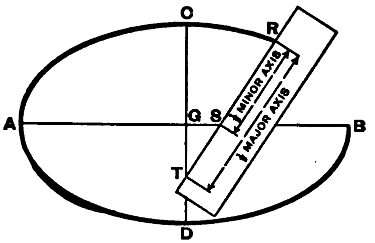


Fig. 173. Ellipse

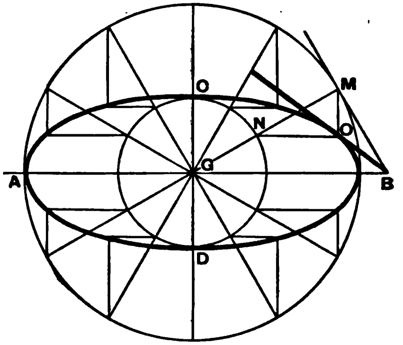


Fig. 174. Ellipse

Fig. 175. Having given the major and minor axes. From the extremity of the major axis, draw *B*6 parallel and equal to half the minor axis; divide it into any number of equal parts; in this case six. Divide *BG* into the same number of equal parts. Through points 1, 2, 3, etc., on *B*6, draw lines to extremity *C* of the minor axis. From *D*, the other extremity of the minor axis, draw lines through 1, 2, 3, etc., on *BG*, intersecting the above lines in points which will lie on the required ellipse.

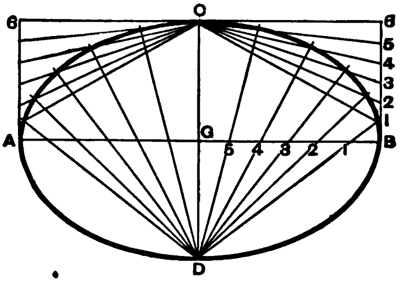


Fig. 175. Ellipse

Fig. 176 illustrates the construction by this method when conjugate diameters *AB* and *CD* are given, and Fig. 177 is the construction when a chord and either axis be given.

111. The Ellipse. Approximate Method. -- Fig. 178. For many purposes in drawing it is sufficiently accurate to describe the ellipse by means of four circular arcs of two different radii. The following is one of several methods: On the minor axis lay off *GF* and *GO* equal to the difference between the major and minor axes. On the major axis lay off *GE* and *GL*, equal to three-quarters of *GF*. Connect points *F*, *E*, *O*, *L*, and produce the lines. With center *E* and radius *AE* describe arc *HAM*. With center *F* and radius *FD* describe arc *KDH*. In like manner describe *MCR* and *RBK* from centers *O* and *L*. Do not use this method when the major axis is more than twice the minor.

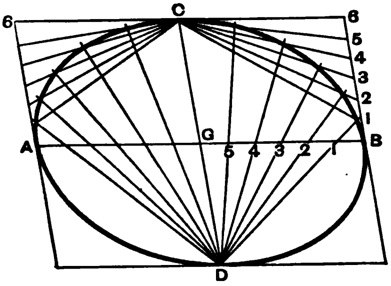


FIG. 176. ELLIPSE

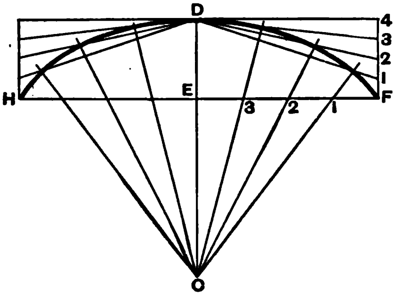


FIG. 177. ELLIPSE

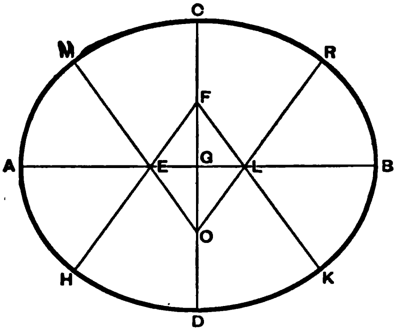


FIG. 178. ELLIPSE

112. The Parabola. — Fig. 179, is a curve generated by a point moving in a plane so that its distance from a fixed point shall be constantly equal to its distance from a given right line.

Point F, is the Focus, CD is the given right line called the Directrix, and AB, a perpendicular to CD through F, is the Axis. V, the intersection of the axis with the curve, is the Vertex, and by the definition of a parabola it must be equidistant from the focus and directrix.

113. The Parabola. Directrix Method. — Fig. 179. Having given the focus F and the directrix CD. Bisect FA to find the vertex V. Through any point on the axis, as L, draw MN parallel to the directrix and with radius LA describe arc 1 from focus F as center, intersecting line MN at points M and N. These are points in the parabola. Similarly obtain other points and draw the required curve. A Tangent to the curve may be drawn at any point M by drawing MO parallel to the axis and bisecting the angle OMF. MT is the required tangent at M. Since the angle $T'MR$ is equal to the angle TMF, it follows that MR would be the direction of a ray of light emitted from the focus F and reflected from the parabola at M. The locomotive head light is constructed on this principle.

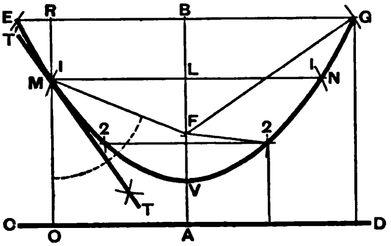


Fig. 179. Parabola

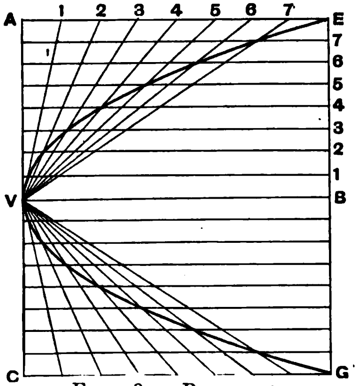


Fig. 180. Parabola

114. The Parabola. Parallelogram Method. — Fig. 180. Having given the abscissa VB, and the double ordinate GE. Draw AE and CG parallel and equal to VB. Divide AE and BE into the same number of equal parts. From the divisions on *BE* draw parallels to the axis and from the divisions on *AE* draw lines converging to the vertex *V*. The intersection of these lines, 1 and 1, 2 and 2, etc., will determine points in the required curve. In like manner obtain the opposite side.

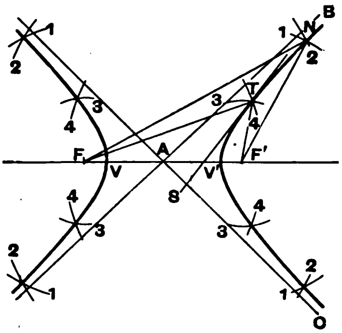


Fig. 181. Hyperbola

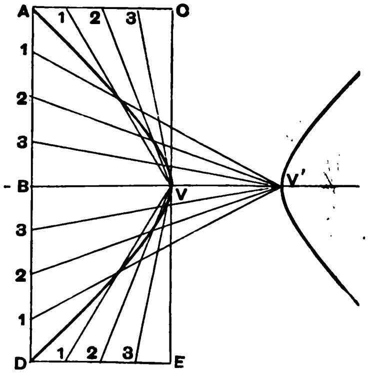


Fig. 182. Hyperbola

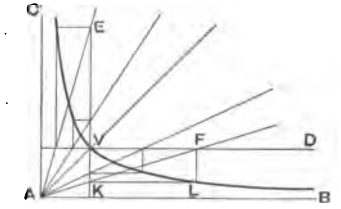


Fig. 183. Equilateral Hyperbola

115. The Hyperbola. — Fig. 181 is a curve generated by a point moving in a plane, so that the *difference* of the distances from this point to two fixed points shall be constant. It will be observed that this definition differs from that of the ellipse by using the word *difference* instead of *sum*. The two fixed points *F* and *F'* are the Foci, and the line *VV'* is the constant distance called the Transverse Axis. From the definition it will be seen that *VV'* is equal to *TF* minus *TF'*, or *NF* minus *NF'*, etc. There will be two branches to the curve.

116. The Hyperbola Construction. — Fig. 181. Having given the transverse axis *VV'* and the foci *FF'* to describe an hyperbola. With any radius greater than *F'V*, from centers *F* and *F'* describe arcs 2; from the same centers, with radii decreased by *VV'*, describe arcs 1 intersecting arcs 2. These points of intersection will be points in the required curve. A tangent, *ST*, may be drawn to any point, *T*, by bisecting the angle *FTF'*.

117. The Hyperbola. Parallelogram Method. — Fig. 182. Having given the axis *VV'*, a double ordinate *AD*, and *BV*, its distance from the vertex. Draw *AC* and *DE*, parallel and equal to *BV*. Divide *AB* and *AC* into the same number of equal parts, and from points on *AC* draw lines converging to the vertex *V*. From points on *AB* draw lines converging to the vertex *V'*. The intersection of these lines 1 and 1, 2 and 2, etc., will be points in the required hyperbola.

118. The Equilateral Hyperbola. — Fig. 183. If the hyperbola is derived from a cone, the elements of which make angles of 45° with the axis, the curve is called an equilateral hyperbola. A knowledge of the construction of this curve is important, as it is the best approximation to the expansion curve of steam and is much used in connection with indicator diagrams.

In Fig. 183, *A* is the vertex and *AB*, *AC* the elements of a cone from which the curve is derived. *V* is the vertex of the hyperbola and *AV* is one-half the transverse axis. Draw *VD* and *VE* parallel to *AB* and *AC* respectively. Draw any line *AF* radiating from *A* and intersecting *VD* and *VE*, or these lines produced. From the points of intersection *F* and *K* draw perpendiculars *FL* and *KL*. The intersection of these perpendiculars, *L*, will be a point in the hyperbola. It will be observed that the curve on the right of *V* is approaching *AB*, and on the left it is approaching *AC*; but it will meet and be tangent to these lines only at infinity. Lines having this relation to an hyperbola are called the ASYMPTOTES of the curve. The asymptotes of the hyperbola illustrated in Fig. 183 are *AB* and *AC*.

119. The Spiral is a curve generated by a point moving in a plane about a center from which its distance is continually increasing.

Imagine a right line, *AB*, Fig. 184, free to revolve in the plane of the paper about one of its extremities, *A*, as an axis. Also, conceive a point free to move on this line. Three classes of lines may now be derived in the following manner: If the line be stationary and the point moves, a straight line will be generated; if the point be stationary and the line revolves, a circle will be generated; if both point and line move, a spiral will be generated. By varying the relative motion of point and line the character of the curve will be changed and the various classes of spirals described.

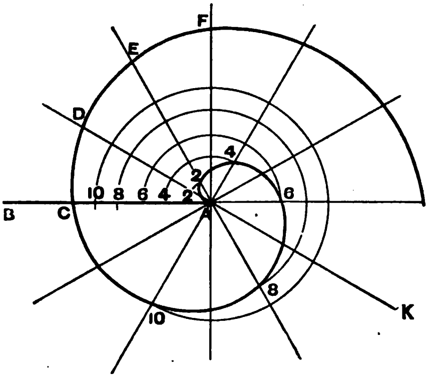


FIG. 184. SPIRAL

120. The Equable Spiral. — Fig. 184. If the motion of the line and the point be uniform the equable spiral will be generated. This is also called the SPIRAL OF ARCHIMEDES. The line *AB* is called the RADIUS VECTOR, and the radial distance traversed by the point during one revolution of the radius vector is called the PITCH. Twelve successive positions of the radius vector are shown by *AC*, *AD*, *AE*, etc. The distance of the point from the center being increased by one-twelfth of the pitch, *AC*, for each one-twelfth of a revolution of the radius vector. In practice, determine at least twenty-four points, and lightly sketch the curve freehand. This is the curve used in the cam for uniform motion.

121. Involutes. — This class of spirals may be generated by unwinding a perfectly flexible but inextensible cord from a polygon of any number of sides, the names of the involutes being derived from the polygons which determine their form. The curves consist of circular arcs having the vertices of the polygons for centers, and radii increasing by an amount equal to the length of the sides.

Fig. 185 is the involute of a square, drawn by describing the quadrant 4–5 from center 1 with radius 1–4; then the quadrant 5–6 from center 2 with radius 5–2, and so on until the desired length of curve shall have been drawn. If two opposite sides of the square become infinitely small, the result will be a right line, the involute of which is shown in Fig. 186. Again, if the number of sides of the polygon become infinite, we shall obtain the involute of a circle, as in Fig. 187. The accuracy of this curve will depend on the number of points in the circle; in this case there are twenty-four.

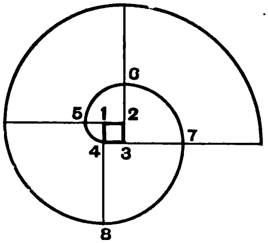


FIG. 185. INVOLUTE OF SQUARE

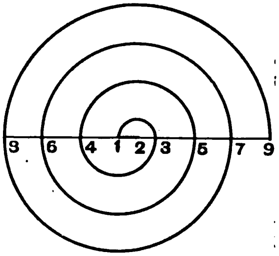


FIG. 186. INVOLUTE OF A RIGHT LINE

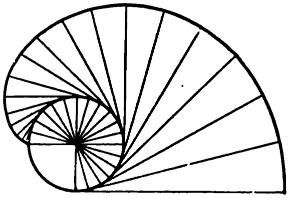


FIG. 187. INVOLUTE OF A CIRCLE

The involute of a circle is the curve most largely used for describing the curves of gear teeth.

122. The Helix. — If the line on which the generating point is supposed to move be made to revolve about an axis with which it makes an angle of less than 90°, thus generating a cylinder or cone, a class of curves known as helices will be described. If the line *AB*, Fig. 188, be parallel to the axis about which it revolves, and the generating point moves on this line, three classes of lines may be described, as in the case of spirals.

A circle will be generated when the point is stationary and the line revolves; a right line will be generated when the line is stationary and the point moves on the line; and since the circle and right line do not lie in the same plane, the result will be a helix when these motions take place simultaneously. The distance traversed by the generating point on the line *AB* during one revolution is called the Pitch. The motion of line and point being in general uniform, the curve is described as follows: Having assumed any desired number of equidistant positions of the generating element *AB*, as 1, 2, 3, 4, etc., the pitch should be divided into the same number of parts, as shown by the horizontal lines drawn through $1'$, $2'$, $3'$, $4'$, etc. When the element shall have moved through one of its divisions to the position 1, which in this case is one-twelfth of a revolution, the generating point will have moved on the generating line through one-twelfth of the pitch, and the point *K* will be determined. Also, when the element has made one-quarter of a revolution, the point will have traversed one-quarter of the pitch and be at *C*. As the rate of curvature is most rapid at the points of tangency, *A*, *D*, and *B*, it is desirable to obtain a greater number of points by subdivision, as shown in the figure. In Fig. 188 the helix is right-handed, and single, but if a double helix is required, draw a parallel curve beginning at the point $6'$, opposite *D*.

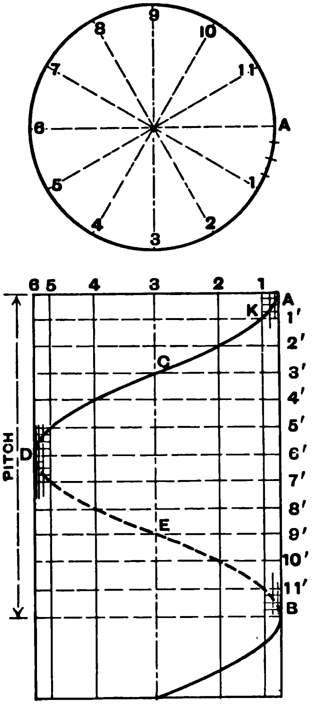


Fig. 188. Helix

A Conical Helix is generated by the motion of a point on an element of a cone. The pitch is measured parallel to the axis, as in the preceding case.

Geometrical Problems

A $4''$ square is sufficient space for each problem. All of the work is to be performed with a 4H lead pencil and the greatest possible precision must be used. When two methods are given, the problem should be constructed by the draftsman's method and tested by the geometrical method. In each case make reference to the Article illustrated by the problem.

1. Bisect a line $3''$ long.
2. Draw a line $2\frac{7}{8}''$ long and erect a perpendicular $1\frac{3}{8}''$ from one end. Do not use a T square.
3. From a point nearly over the center of a line $3\frac{1}{4}''$ long draw a perpendicular to the line. Do not use a T square.
4. From one extremity of a line $3\frac{1}{2}''$ long draw a second line making an angle of 45° with the first. Similarly construct an angle of 30° at the other end.
5. From one extremity of a line $3\frac{1}{2}''$ long draw a second line making an angle of 60° with the first. Similarly construct an angle of 75° at the other end.
6. Construct an equilateral triangle having a base of $2\frac{15}{16}''$.
7. Construct a right-angle triangle having a base of $2\frac{3}{4}''$ and one angle of 30°.
8. From a point on a circle $2\frac{7}{8}''$ in diameter draw a tangent.
9. Draw a tangent to the middle point of the arc of a circle of $2\frac{1}{4}''$ radius having a chord of $2\frac{1}{2}''$. Do not use the center of circle.
10. Draw a tangent to a circle $2\frac{3}{8}''$ in diameter from a point $2\frac{1}{4}''$ from center of the circle.
11. Prescribe three points and draw a circle through them.
12. Inscribe a circle within a triangle having a base of $3\frac{1}{8}''$ and equal sides of $3\frac{5}{8}''$.

13. Draw a right-angle triangle having a side $2\frac{1}{2}''$ long and one of the oblique angles 30°. Circumscribe a circle about this triangle.
14. Within a circle $3\frac{1}{2}''$ in diameter inscribe an equilateral triangle.
15. Within a circle $3\frac{1}{2}''$ in diameter inscribe a hexagon.
16. About a circle $2\frac{7}{8}''$ in diameter circumscribe a hexagon.
17. Draw a hexagon having its long diameter $3\frac{1}{2}''$.
18. Draw a hexagon having its short diameter $3''$.
19. Draw a hexagon having one side $1\frac{5}{8}''$.
20. Draw a hexagon having its short diameter $2\frac{3}{4}''$ and one side horizontal.

Conic Section Problems

These problems require a space of $5'' \times 7''$.

1. Draw an ellipse having the minor axis $4''$ and the distance between the foci $4\frac{1}{2}''$. Construct by Art. 107. Draw the conjugate diameters, one of which makes an angle of 15° with the major axis.
2. Draw one-half of an ellipse having the major axis $6\frac{1}{2}''$ and the distance between the foci $4\frac{1}{2}''$. Construct by Art. 110.
3. Draw an ellipse having the major axis $6\frac{1}{2}''$ and the minor axis $3''$. Construct by Art. 108.
4. Draw an ellipse having the major axis $5\frac{1}{4}''$ and its minor axis $4\frac{1}{2}''$. Construct by Art. 111. Test one-quarter of the curve by Art. 108.
5. Draw an ellipse having the major axis $5\frac{1}{2}''$ and the distance between foci $3\frac{1}{2}''$. Construct by Art. 107. Draw two conjugate diameters, one of which makes an angle of 75° with the major axis.
6. Draw an ellipse having the minor axis $3\frac{1}{2}''$ and the distance between the foci $5''$. Construct by Art. 108. Draw a tangent to the curve at a point $2\frac{3}{4}''$ distant from the minor axis.
7. Draw one-half of an ellipse having its major axis $6\frac{1}{2}''$ and its minor axis $4\frac{1}{2}''$. Construct by Art. 110.
8. Draw an ellipse having a major axis $4\frac{7}{8}''$ and the minor axis $2\frac{3}{4}''$. Construct by Art. 109.

9. Draw an ellipse having the major axis 6″, and the minor axis 4″. Construct by Art. 107.
10. Draw an ellipse having its minor axis 4″, and the distance between the foci 3″. Construct by Art. 108. Draw two conjugate diameters, one of which makes an angle of 30° with the major axis.
11. Draw a segment of an ellipse having an axis of 4″ and a $5\frac{1}{2}''$ chord which intersects the axis at $1\frac{1}{4}''$ from its extremity. Construct by Art. 110.
12. Draw a parabola having the focus $\frac{3}{4}''$ from the directrix. Draw a tangent to any point of the curve. Construct by Art. 113.
13. Draw a parabola having given the abscissa 6″ and double ordinate $4\frac{1}{2}''$. Construct by Art. 114.
14. Draw a parabola having the focus 1″ from the directrix. Draw a tangent to the curve at a point $1\frac{3}{4}''$ from the focus. Construct by Art. 113.
15. Draw a parabola having given the abscissa $5\frac{1}{2}''$ and double ordinate 4″. Construct by Art. 114.
16. Draw an hyperbola having its transverse axis $1\frac{1}{2}''$ and distance between the foci $2\frac{1}{8}''$. Draw a tangent to the curve at a point $1\frac{5}{8}''$ from the vertex.
17. Draw an hyperbola having its transverse axis $1\frac{1}{2}''$, a double ordinate $4\frac{3}{4}''$ and its distance from the vertex $1\frac{7}{8}''$. Construct by Art. 117.
18. Draw an hyperbola having its transverse axis $1\frac{3}{4}''$ and distance between the foci $2\frac{1}{4}''$. Draw a tangent to the curve from a point $1\frac{7}{8}''$ from the vertex. Construct by Art 116.
19. Draw an hyperbola having the transverse axis $1\frac{3}{4}''$, a double ordinate $4\frac{1}{2}''$ and its distance from the vertex $2\frac{1}{4}''$. Construct by Art. 117.

CHAPTER IX

LETTERING

123. Lettering. — In addition to the graphic description which every drawing is designed to express, it is necessary to give the figured dimensions, and frequently to add the title, names of parts and written notes descriptive of the material and character of finish. Such notes must be lettered and not in script.

The character of the lettering used in making these notes is of great importance, not only to the appearance of the drawing, or sketch, which may be ruined by poor lettering and figures, but because illegibility is a positive danger. For these reasons, it is very desirable to obtain a knowledge of the characteristics of good lettering which, with little practice will suffice for all ordinary work.

Mere inequalities in lines due to insufficient practice in the handling of a pencil or pen will not materially affect the appearance of letters or figures provided there be conformity to two features which are essential.

1. Uniformity in the height of letters.
2. Uniformity in the slant.

The observance of these two essentials are important in the writing of script but defects are not so apparent as in lettering.

Since the first of these requirements, equality in height, can be obtained by lettering between parallel lines, there is no excuse for its non-observance, but to obtain conformity with the second, the character of the letters must be studied.

124. The Inclined Gothic. — Fig. 189 is the only type of lettering that will be recommended for this elementary work. It should be made with a single stroke of the pen, or pencil, and not shaded or increased in width beyond that determined by the width of the line made by the pen without pressure.

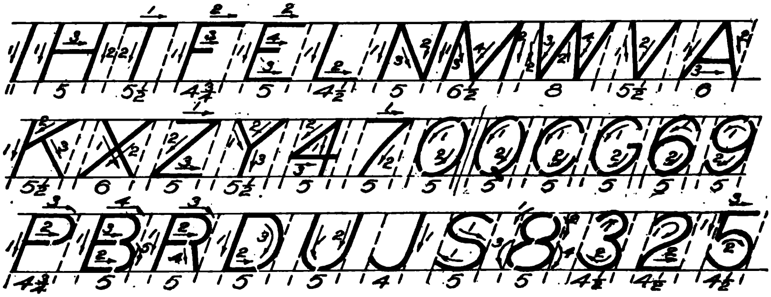


FIG. 189. UPPER CASE INCLINED GOTHIC

The slant of the letters in the alphabet is about 67° but is easily determined as indicated in Fig. 190, by making the ratio of the height to the inclination 8 to 3 which being obtained should be used as a guide for all the inclined strokes of the *I*, *H*, *T*, *L*, etc. Other letters having strokes at other angles such as the *M*, *X*, and *K* together with the curved forms of the *O*, *G*, and *C* must also present the appearance of having the same slant.

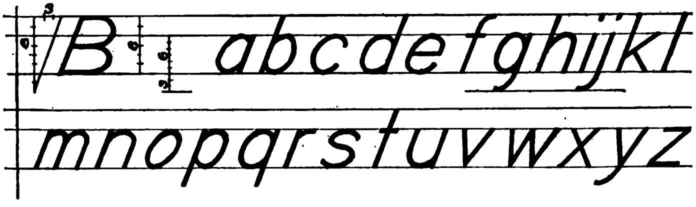


FIG. 190. LOWER CASE INCLINED GOTHIC

125. The Lower Case Inclined Gothic is illustrated by Fig. 190. These letters are made two-thirds the height of the capitals and the proportion of width to height, which is about 5 to 6, is similar to the capitals. The variations from this normal proportion are shown in Fig. 192.

126. Practice in the Slant of Letters. — It is of first importance to make such a study of the forms of letters as will enable one to secure uniformity in the slant. Omitting such details of lettering as relate to the precision of lines, the exact ratio of width to height and certain effects that are produced by optical illusions, it is well to consider the salient features which alone determine the slant. Fig. 191 illustrates two lines of letters marked correct and incorrect, but this refers to slant only, as the upper line of letters are very crudely made with irregularities in line and lack of perfect proportion, but the slant of the letters is uniform and the general effect good while the unevenness, due to lack of uniformity in slant of the lower line letters is apparent at a glance.

Such letters as *H*, *T*, *L*, *F* and *E* require little attention save that of making the down strokes parallel, although the horizontal strokes of the *E* influence the slant as indicated in the lower line. But in such letters as the *V*, *A*, and *W*, in which lines are drawn at various angles, the slant of the letters is governed by the position of the vertex of the angle of the slant lines. Previous to drawing the lines of the *V* or *A*, one must determine the width of the letter and through the middle point of this determined width, draw, or imagine drawn, a line of the required slant which will determine the position of the vertex. The *W* is especially difficult until one learns to locate the points 1, 2, 3, 4, 5, as indicated. The good letterer does this mentally, but the novice should estimate and mark these points before making the stroke. A common error in the *X* is shown in the second line by a failure to draw or think of the slant lines.

The *O* forms in the second line will not be found difficult if the slant lines be drawn first and the points of tangency of the curves be located at the middle point as indicated. It is not the regularity of the curve but the observance of these characteristics which insure good lettering.

The figures 2 and 5 are commonly made incorrect due to a failure in observing the slant. Referring to Fig. 191, these figures are made with equal care in both lines, but the error in the second line is apparent at a glance.

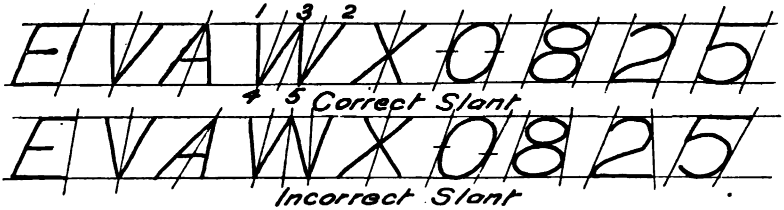


FIG. 191

All of the refinements of lettering have been omitted from the letters and figures of the first line of letters in Fig. 191, but the uniformity in height and slant has been maintained, thus obtaining a degree of uniformity which is of first importance in lettering.

In Fig. 189, the capital letters are classified with respect to the character of the strokes and suggest an order for the practice in making them. The height of the letters being 6 units, the width in the same unit is given below each letter. The direction and order of the strokes is also indicated.

Fig. 192 illustrates another classified grouping of the letters with some of the refinements more clearly set forth as explained in the following text.

127. Correct Proportions of the Inclined Gothic. — In comparing the sketched letters and figures of Fig. 191 with the more accurately drawn alphabet of Fig. 189 many slight deviations from the exact form will be observed, such for instance, as the making of the upper part of the *E*, *R*, and *X* slightly narrower than the lower part, also the making of the horizontal strokes of the *B*, *F*, and *H* slightly above the center, while that of *A* is below the center of the letter. There are slight differences in the width of letters as shown by Figs. 189 and 192.

The details of these differences together with the reasons therefor are as follows:

Letters are made to appear as nearly as possible of uniform width. A good proportion is, height 6 units and width 5 units.

B D E H N R S U Z are letters of normal width.

C G O Q are made slightly in excess of normal. Since a circle will appear smaller than a square of the same size, the round letters are made a little wider and higher than normal, as shown in Fig. 192.

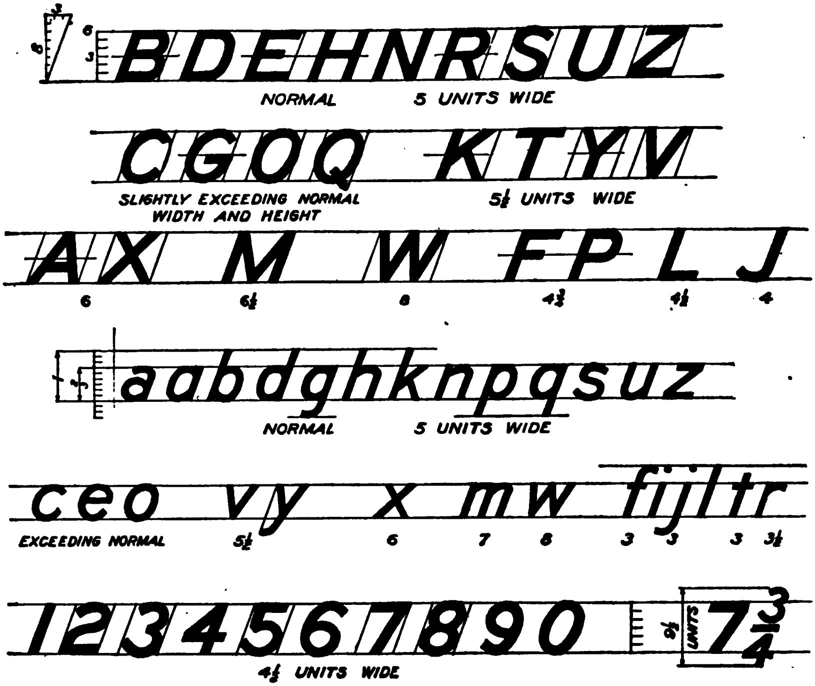


FIG. 192

S J U are made slightly longer than the normal letter, for the reason stated above, the rounded portions extending slightly over the guide lines.

K T Y V. Because of the slanting lines of the *K*, *Y*, and *V* these letters appear narrower than they really are, consequently they are made a little wider than normal. Because the top member of *T* is bisected by the vertical member, it also appears narrower than it really is and therefore is made slightly wider than normal. These letters are 5½ units wide.

A and *X* are made as wide as they are high — 6 units.

W, because of its congested appearance and the slant of its outside lines must be made the broadest letter — 8 units wide.

F and *P* are slightly narrower than normal — 4¾ units.

L. Because there is but one horizontal member, and that entirely on one side of the vertical line, the *L* appears too wide if made of normal width, consequently it is narrowed to 4½ units.

J should be 4 units wide.

The tops of letters are made narrower than the bottoms so as to avoid a top-heavy effect. These letters are *B*, *E*, *R*, *S*, *K*, *X*, and *Z*. *S* and *X* are narrowed on the right hand side only, and *Z* is narrowed on the left hand side only.

The center horizontal members of *B*, *E*, *H*, *S*, and *F* are slightly above the center. Because there is no lower horizontal member to *P* and *R*, the center member is in the center, or even slightly below the center.

The order and direction of making the strokes are indicated in Fig. 189. These vary somewhat with draftsmen but that suggested is the most simple.

A classification of letters desirable for practice and which leads from the simple to the more difficult is as follows: — *I H T L E F K N M A V W X Y Z — 74 — D P B R — O Q C G U J — 69 — 2358 — S.*

To practice the forms of the letters, begin by drawing a series of parallel lines, as in Fig. 190, to limit the height of the upper and lower case letters. It is desirable, also, to draw slant lines at intervals observing the suggested angle of Fig. 190. This will assist in maintaining a constant slant of the letters.

In the preliminary practice of the O forms, it is best to draw the slant lines that limit the width of these forms, which will enable one to observe the position of the points of tangency that is so essential in determining the character of this type of letter.

VOCABULARIES

VOCABULARY FOR PIPE FITTINGS

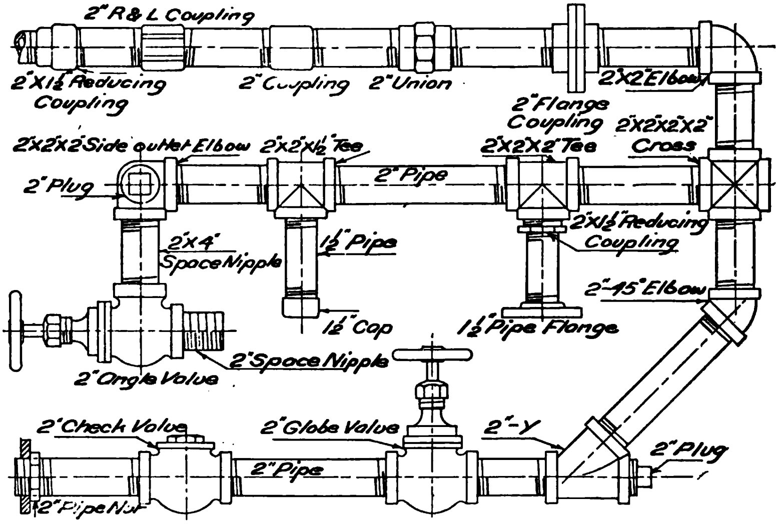


FIG. 193

Fig. 193 illustrates various types of pipe fittings with their names and method of designating.

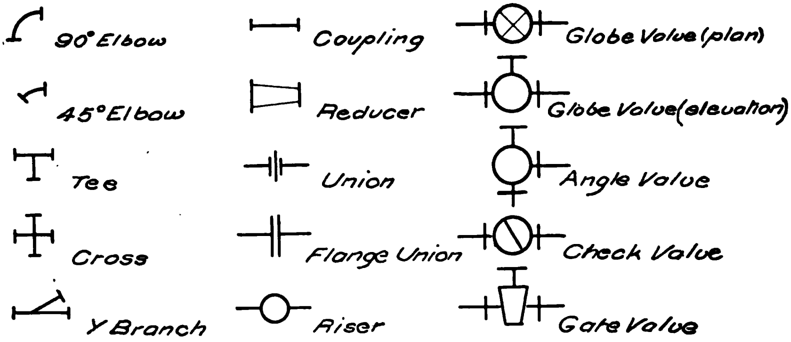


FIG. 194

Fig. 194 illustrates an abbreviated form of symbols, or vocabulary, for the several fittings of Fig. 193, an[1] are such as would be used in practice.

VOCABULARY FOR RIVETS AS USED IN STRUCTURAL WORK

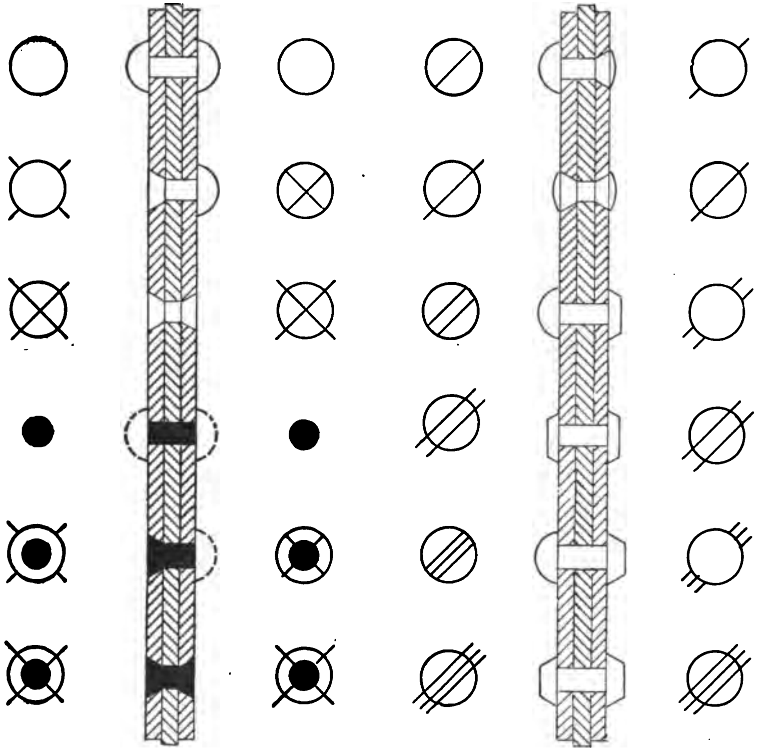


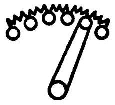
FIG. 195

The Fig. 195 illustrates sectional views of plates united by rivets of different character which it is required to distinguish by a simple notation.

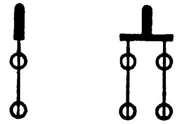
To the right and left of these sections, the symbols are shown which indicate by means of a circle and diagonal lines the character of the rivet and the side from which it is shown. Those shown in black indicate the hole for the rivet which is to be driven in the field, when the work is assembled. In structural drafting the rivets are indicated as seen from one side of the plate and therefore each form of rivet may have two symbols.

VOCABULARY OF TERMS FOR ELECTRICAL EQUIPMENT

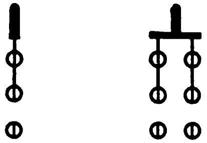
KNIFE SWITCHES.



RHEOSTAT.

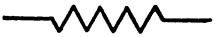


SINGLE POLE. DOUBLE POLE.
SINGLE THROW.

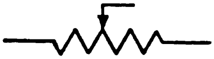


SINGLE POLE. DOUBLE POLE.
DOUBLE THROW.

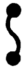
QUICK ACTING CIRCUIT CONTROLLERS MAY BE DISTINGUISHED BY THE LETTER "Q"



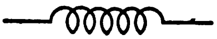
FIXED RESISTANCE.



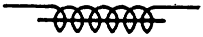
VARIABLE RESISTANCE.



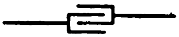
FUSE.



IMPEDANCE WITHOUT
IRON CORE.

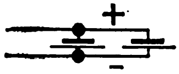


IMPEDANCE WITH
IRON CORE

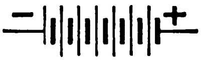


CONDENSER.

BATTERY.

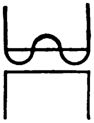


CELLS IN MULTIPLE.



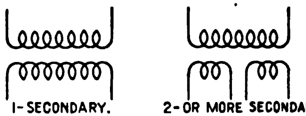
CELLS IN SERIES.

SPECIFY TYPE AND NUMBER OF CELLS.



RECTIFIER.

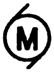
D = DRY BATTERY.
G = GRAVITY "
P = POTASH "
S = STORAGE "
EXAMPLES: 16P, 10S, ETC.

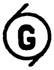


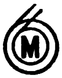
I-SECONDARY. 2-OR MORE SECONDARIES.
TRANSFORMERS.

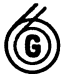
Copied by permission from Standard Symbols recommended by the American Railway Association.

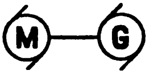
VOCABULARY OF TERMS FOR ELECTRICAL EQUIPMENT

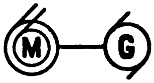

D.C. MOTOR.

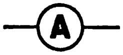

D.C. GENERATOR.

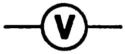

A.C. MOTOR.

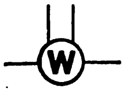

A.C. GENERATOR.

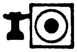

D.C.-D.C. MOTOR-GENERATOR.

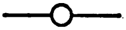

A.C.-D.C. MOTOR-GENERATOR.

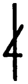

AMMETER.


VOLTMETER.

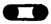

WATTMETER.


TELEPHONE.

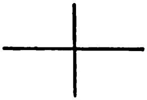

INCANDESCENT LAMP.

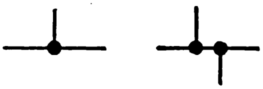

LIGHTNING ARRESTER.

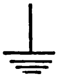
SINGLE.

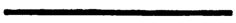

DOUBLE.

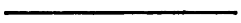
TERMINALS.

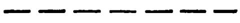

WIRES CROSS.

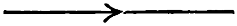

WIRES JOIN.


GROUND.


"COMMON" WIRE.


OTHER THAN "COMMON" WIRE.


TRACK CIRCUIT WIRE.


DIRECTION OF CURRENT.

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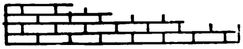
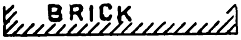
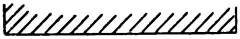
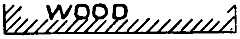
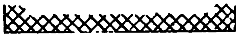
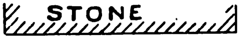
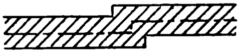
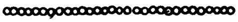
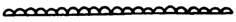
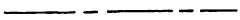
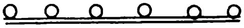
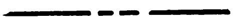
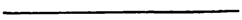
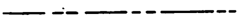
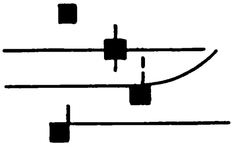
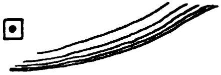
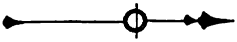
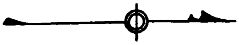
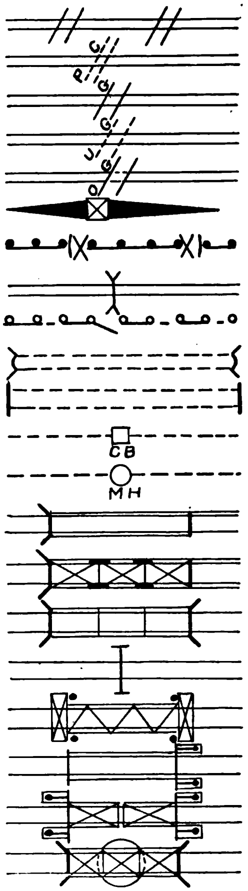
VOCABULARY OF TERMS USED FOR LAND COURT PLANS

Buildings of brick, A or B	A	
	B	
Buildings of wood, C or D	C	
	D	
Buildings of stone, E or F	E	
	F	
Buildings with brick partition walls		
Stone wall		
Faced or retaining wall		
Fence		
Fence, where posts are to be shown		
Town or county boundary line		
Private ownership line, K or L	K	
	L	
Stone bound		
Stone bound where property lines intersect		
Stone bound marking a tangent point		
Stone bound at intersection of streets		
Triangulation station		
Transit point		
Stake		
Mean high-water line		
True meridian		
Magnetic meridian		

VOCABULARY OF TERMS USED FOR RAILROAD CROSSINGS, CULVERTS AND BRIDGES

Street and Public Road Crossings
Private Road Crossing
Road Crossing at Grade
Road Crossing under Grade
Road Crossing overhead
Crossing Gate
Turnstile
Cattle Guard
Farm Gate
Masonry Arch or Flat Top Culvert
Pipe or Wood Box Culvert or Drain
Catch Basin
Manhole
Girder
Truss
Trestle
Signal Bridge
Lift Span
Bascule, Single Leaf
Bascule, Double Leaf
Draw Span



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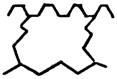
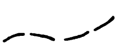
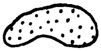
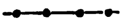
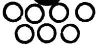
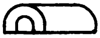
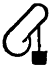
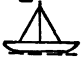
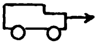
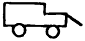
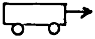
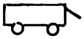
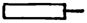
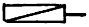
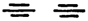
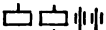
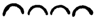
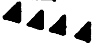
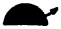
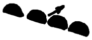
VOCABULARY OF MILITARY TERMS (BRITISH)

Any trench organized for fire	
Approximate line, reported by observers but not confirmed by photographs	
Wire entanglements	XXXXX
Ground cut up by artillery fire	
Enemy tracks	=====
Buried pipe line	
Supply depot	
Observation post	
Dugout	■
Earthwork	●
Machine gun emplacement	♂ or MG
Trench mortar	◉ or T M
Listening post	■ L or LP
Mine crater, unfortified	✱
Mine crater, fortified	
Organized shell holes	
Anti-aircraft gun	
Airship shed	
Balloon	
Barge	
Fire	F
Railhead	Ⓗ
Power transport, moving	
Power transport, stationary	
Horse transport, moving	
Horse transport, stationary	
Infantry, moving	
Cavalry, moving	
Artillery, moving	
Holding line in action	
Post	
Patrol	
Gun emplacements	
Battery of guns inactive	○
Single guns, inactive	○ ○ ○
Howitzer battery, active	
Single howitzers, active	
Doubtful battery, active	
Doubtful guns active	

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